Kern River Watershed Coalition Authority

Comprehensive Groundwater Quality Management Plan

Kern County, California • February 2015

Prepared for:

Kern River Watershed Coalition Authority

Prepared by:

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Provost & Pritchard Consulting Group
Bakersfield, California

Certifications

This Comprehensive Groundwater Quality Management Plan is signed by the following certified professional:

Provost & Pritchard Consulting Group

Project Team

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Abbreviations

AFY/ac .... Acre-feet per year per acre

AGR .... Agriculture

AEWSD .... Arvin-Edison Water Storage District

AFY .... Acre-feet per year

A/R .... Applied versus removed

ASA-CCA .... American Society of Agronomy Certified Crop Advisors

BGS .... Below ground surface

CDFA .... California Department of Food and Agriculture

CDPH .... California Department of Public Health

CGQMP .... Comprehensive Groundwater Quality Management Plan

CIMIS .... California Irrigation Management Information System

Coalition .... Kern River Watershed Coalition Authority

COC .... Constituent of concern(s)

CVHM .... Central Valley Hydrologic Model

CVRWQCB .... Central Valley Regional Water Quality Control Board

CV-SALTS .... Central Valley Salinity Alternatives for Long-Term Sustainability

DAC(s) .... Disadvantaged community(ies)

Dairy General Order .... Waste Discharge Requirements General Order for Existing Milk Cow Dairies (Order R5-2013-0122)

DBCP 1,2-dibromo-3-chloropropane

DPR .... California Department of Pesticides Regulation

DWR .... California Department of Water Resources

ET .... Evapotranspiration

FT .... Foot/feet

FREP .... Fertilizer Research and Education Program

GAR .... Groundwater Quality Assessment Report

GAMA .... Groundwater Ambient Monitoring & Assessment Program

General Order .... General Order R5-2013-0120

GQMP .... Groundwater Quality Management Plan

GWPA(s) .... Groundwater Protection Area(s)

HVA(s) .... High Vulnerability Area(s)

ILRP....Irrigated Lands Regulatory Program
IND....Industrial
ITRC....Cal Poly Irrigation Training and Research Center
KCWA....Kern County Water Agency
KRWCA....Kern River Watershed Coalition Authority
Mg/L....Milligrams per liter
MCL....Maximum contaminant level
MRP....Monitoring and Reporting Program
MUN....Municipal
NHI....Nitrate Groundwater Pollution Hazard Index
N....Nitrogen
NO_3....Nitrate
NRCS....Natural Resources Conservation Service
RWQCB....Central Valley Regional Water Quality Control Board
SSJVWQC....Southern San Joaquin Valley Water Quality Coalition
SWRCB-AEP....State Water Resources Control Board Agricultural Expert Panel
SWRCB-DDW....State Water Resources Control Board Division of Drinking Water
TLHR....Tulare Lake Hydrologic Region
Tulare Lake Basin Plan....Water Quality Control Plan for the Tulare Lake Basin
UCCE....University of California Cooperative Extension
USDA....United States Department of Agriculture
USGS....United States Geological Survey
WDR(s)....Waste Discharge Requirement(s)
WRMWSD....Wheeler Ridge-Maricopa Water Storage District

1 Introduction and Background

This Comprehensive Groundwater Quality Management Plan (**CGQMP**) has been prepared on behalf of the Kern River Watershed Coalition Authority (**KRWCA** or **Coalition**) in response to Waste Discharge Requirements (**WDR**) General Order R5-2013-0120 (**General Order**). Groundwater Quality Management Plans (**GQMP**) are required in areas of confirmed exceedances of water quality objectives, defined as high vulnerability areas (**HVAs**) by the Groundwater Assessment Report (**GAR**), as required by the Basin Plan for a constituent discharged by agriculture, and/or when an Executive Officer determines trends of degradation contributed to by irrigated agriculture will threaten applicable beneficial uses. In accordance with the outline in Attachment A and the specifications in Attachment B, Monitoring and Reporting Program (**MRP**), to the General Order, this GQMP shall;

- Investigate potential irrigated agricultural sources of waste discharge to groundwater;
- Review physical setting information for the plan area such as geologic factors and existing water quality data;
- Develop a strategy with schedules and milestones to implement practices to ensure discharge from irrigated lands are meeting Groundwater Receiving Water Limitation;
- Develop a monitoring strategy to provide feedback on GQMP progress;
- Develop methods to evaluate data collected under the GQMP; and,
- Provide reports to the Central Valley Water Board on progress.

Rather than submitting separate management plans for noted exceedances, the KRWCA has elected to submit a single comprehensive plan along with the KRWCA GAR. In fulfilling these requirements the KRWCA will implement a process to encourage adoption of effective practices by members of the KRWCA. The conclusions of this CGQMP express the necessity of extensive outreach and education to support the implementation of effective irrigation and nutrient management throughout the Coalition area. This CGQMP also outlines the limitations of available data, the physical barriers to representative groundwater monitoring, and the complex dynamics of decreasing the potential to leach nitrate from irrigated agriculture.

The KRWCA boundary generally coincides with the Kern River Watershed boundary (**Figure 1**), and encompasses 3.5 million acres of land (gross acres), of which approximately 622,200 acres are irrigated (irrigated acres). As of February 4, 2015, 858 growers were registered as KRWCA members. At that time, this represented 522,833 irrigated acres, or approximately 83% of all irrigated land. Of the gross acres, approximately 97,600 acres are classified as urban, commercial, or industrial areas. The largest population center within the KRWCA is the City of Bakersfield.

The KRWCA area is separated into the primary boundary, which includes the valley floor, and a secondary boundary that contains very little irrigated acreage. The primary boundary includes approximately 1,023,600 gross acres of land that are within the boundary of the Kern County groundwater subbasin. This includes approximately 619,200 irrigated acres on the San Joaquin Valley floor. The Upper Kern River Watershed is located almost exclusively within the KRWCA secondary boundary and encompasses approximately 1.5 million acres in the southeastern portion of the San Joaquin Valley.

The soils, geology, hydrogeology, and climate of the KRWCA all significantly impact the region's agriculture. In the KRWCA primary boundary area on the Kern County valley floor, soils have two general origins that are approximately delineated by the trough of the valley. The eastern alluvial fans were deposited primarily through runoff and sediment transport from the Sierra Nevada, Tehachapi, and Transverse Mountain ranges. These soils are of igneous and metamorphic origin; typically well drained, lower in salinity, and of ideal quality for agriculture. The western alluvial fans originated from Coastal Range sedimentary rock formed on the sea bottom. This region tends to have more areas with poorly drained soils of relatively marginal quality. Many of the soils on the west side of the valley required some reclamation before crops could be grown profitably.

The primary KRWCA area is located mostly within the southern portion of the San Joaquin Valley, a long structural trough filled to a depth of up to 10,000 feet of marine and continental sediments. The continental sediments represent a variety of depositional environments including fluvial, deltaic, lacustrine, and alluvial fan sequences, and form an alluvial wedge that thickens to the west across the valley. The secondary KRWCA area extends over a large area of varying geologic and hydrogeologic environments, including upland areas of igneous and metamorphic rock and small valleys filled with continental sediments. The primary portion of the KRWCA area is located almost entirely in the areas of recent alluvium, and the entire contiguous portion of this area is on the floor of the San Joaquin Valley; see **Section 2.1.3** for additional analysis and regional mapping of surficial geology. The entire KRWCA area is in the Tulare Lake Hydrologic Region (**TLHR**) (DWR 2003).

The assessment of subsurface sediments has focused on the Kern County Subbasin portion of the San Joaquin Groundwater Basin [California Department of Water Resources (**DWR**) Subbasin 5-22.14], as the majority of the primary portion of the KRWCA area overlies this aquifer, and there is very little distinct information regarding the other groundwater sources in either the primary or secondary areas. The United State Geological Survey (**USGS**) Central Valley Hydrologic Model (**CVHM**) estimates the vertical and horizontal aquifer parameters of the entire Central Valley, and was used to represent relative aquifer parameter distribution in the Kern County subbasin. The Corcoran Clay is a regionally extensive low permeability unit located in much of the San Joaquin Valley (Croft 1972). However, in Kern County the Corcoran Clay is not considered to be as low permeability or to function as a continuous aquitard or barrier to vertical flow as it does in the other portions of the Central Valley, most notably to the north. The Corcoran Clay is also present at deeper depths than in other areas of the Central Valley (Schmidt and Associates 2006 and Schmidt and Crewdson, personal communication, October 2012).

The climate of the KRWCA is considered semi-arid to desert. Potential evapotranspiration (**ET**), the amount of water evaporated and transpired from healthy grass in a normal year, is 57.9 inches in the southern San Joaquin Valley (Jones, 1999). Potential ET from May to August varies little, less than 5 percent, from year to year (Sanden, 2014a). Effective precipitation, the portion of precipitation that can be beneficially used by crops, averages 3.4 inches in a normal year (Kern County Water Agency, 2005). As such, local surface water supplies are limited and irrigated agriculture in the region relies on groundwater supplies and imported surface water supplies from the north.

Kern County has the second largest crop-based economic value of agricultural counties in the state and nation, producing over 250 crops; including 30 types of fruit and nuts, over 40 varieties of vegetables, over 20 field crops, lumber, nursery stock, livestock, poultry and dairy products (USDA, 2014). Overall, the proportion of permanent crops grown in Kern has increased significantly in the past 20 years and in the overwhelming majority of cases, the permanent crops are irrigated with highly efficient drip and/or micro-spray irrigation systems. Irrigation is currently the single most expensive component of agricultural production in Kern County. Current irrigation efficiencies in the Kern Subbasin are, overall, some of the highest in the entire Central Valley.

Growers also employ efficient nutrient management because fertilizer additions represent another large expense, in addition to the environmental concerns associated with over-application. Accompanying the widespread conversion from gravity irrigation systems to pressurized systems is the increasing use of fertigation, where liquid fertilizer is delivered to the crop in irrigation water. Pressurized systems allow for accurate fertilizer delivery, whereas surface irrigation is less suited to this practice, although fertigation is used in some surface irrigation systems as well.

1.1 Constituents of Concern

1.1.1 Nitrates

Nitrate is a naturally occurring form of nitrogen that can be formed from atmospheric nitrogen or decomposing organic matter. DWR (1970) noted that weathering granite, shales rich in organic matter, underground peat deposits, oilfield brines, and connate waters are considered potential natural sources of nitrate, and mapped the presence of nitrate in Kern from 1950 to 1969. Nitrate can also be found in groundwater as a result of excess application of nitrogen fertilizers in irrigated agricultural and landscaped areas, percolation from feedlots or dairies, wastewater and food processing waste percolation, and leachate from septic system drainfields (Harter T., et al. 2012).

1.1.1.1 Previous Studies and Monitoring

Data from multiple sources was collected and compiled into a comprehensive groundwater quality database for the KRWCA area to fulfill the requirements of the GAR. This water quality data included available groundwater quality analysis results from 1909 through 2014. Some of the available groundwater quality data was associated with wells for which location information was not available; these data were not included in the analyses presented below. The maximum contaminant limit (**MCL**) of 45 milligrams per liter (**mg/L**) nitrate as nitrate has been used to identify nitrate impacted groundwater in the KRWCA area. For this analysis, it is assumed that all groundwater quality results represent first encountered groundwater; however, most samples were retrieved from production wells and, overall, construction information is unavailable for most wells. Future monitoring programs should include the collection of well construction data to provide additional information on the vertical distribution of these constituents over time.

1.1.1.2 Water Quality Exceedance Mapping

The spatial distribution of maximum concentrations of nitrate (**NO_3^-**) in groundwater wells from 1920 to 2014 is split into three groupings (0-45, 45-90, and greater than 90 mg/L NO_3^-) (**Figure 2**). Recent maximum nitrate concentrations in groundwater between 2000 and 2014 (**Figure 3**) illustrate less data availability but indicate that recent spatial trends remain similar. A geostatistical analysis of the historical and current nitrate groundwater quality data was used to further illustrate areas where groundwater quality may already be negatively impacted. The maximum concentration was calculated for all wells. Within a grid cell of one (1) square mile, the maximum well concentration was taken to represent the maximum nitrate concentration in that area. The area discretization for this analysis was the grid cell for the USGS CVHM; the resulting nitrate distribution is shown on **Figure 4**.

1.2 Geographic Boundaries of Comprehensive Groundwater Quality Management Plan

Areas to be covered by the KRWCA CGQMP include all irrigated acreage, on a field by field basis, identified in the KRWCA GAR to be high vulnerability to nitrate impacts. High vulnerability lands were defined as areas which:

- Fall within groundwater protection areas (**GWPA**) for pesticide leaching by California Department of Pesticide Regulation (**DPR**);
- Are identified by the Nitrate Groundwater Pollution Hazard Index (**NHI**) to have a high nitrate leaching risk from the land surface; or,
- Have groundwater quality exceedances for nitrates and/or pesticides.

The KRWCA identified HVAs are presented on **Figure 5**. The KRWCA high vulnerability area (**HVA**) identifies 211,040 irrigated acres within the primary boundary (34 percent of total irrigated acres) as high vulnerability based on water quality exceedances, the NHI analysis, and DPR GWPAs. See **Table 1** for the high vulnerability area by designation type. The relationship between the three main designation scenarios and respective acreages is presented on **Figure 6**. Of the identified 211,040 KRWCA HVA irrigated acreage, 185,127 irrigated acres (88 percent) is currently enrolled under members in the KRWCA.

1.2.1 Water Quality Exceedances

The analysis of groundwater quality impacts utilizing the USGS CVHM grid cells (one square mile) to identify impacted groundwater quality is a conservative approach, accounting for the spatial imprecision when identifying groundwater well locations and correlating spatial groundwater quality results. Approximately 132,232 irrigated acres are identified as being within CVHM grids impacted by nitrate and/or pesticides, presented on **Figure 7**. The irrigated acreage impacted by nitrates, pesticides, or both nitrate and pesticide exceedances is shown comparatively in **Figure 8**. Of the 132,232 irrigated acres impacted by groundwater quality exceedances, 91 percent of the area is due to just nitrate exceedances, 3 percent is due to just pesticide exceedances, and 6 percent is due to both nitrate and pesticide exceedances.

1.2.2 Nitrate Groundwater Pollution Hazard Index (NHI)

The NHI, an overlay and index assessment method, focuses on the main contributors to nitrate leaching potential related to agricultural land use at the ground surface: soil type, crop type, and irrigation type. Each type of soil, crop, and irrigation method is assigned a hazard value based on its respective potential to leach nitrogen. The hazard values for each parameter (soil, crop and irrigation method) are multiplied to determine the overall nitrate leaching hazard of the given agricultural management system (field). Fields with NHI scores over 20 are considered to have a relatively high nitrate leaching risk, although the scores from 1 to 80 have no linear or quantitative significance; i.e., a score of 60 does not indicate twice as much leaching potential as a score of 30. Rather, the threshold of 20 is used to distinguish between a combination of factors that results in a relatively low leaching potential from one that results in a relatively high leaching potential. The NHI results for the area under evaluation indicate that 83 percent of irrigated lands within the KRWCA fall into the lower nitrogen leaching risk category

(**Figure 9**). This is largely because of the transition to highly efficient and/or uniform irrigation systems used on deep-rooted crops, or irrigation systems with typically lower efficiency and/or uniformity used on fine-textured soils.

2 Physical Setting and Information for CGQMP Area

2.1 Land and Hydrology Characteristics

2.1.1 Land Use

Reviewing historical land use data within the KRWCA primary boundary illustrates the change in crops and irrigation systems that has occurred in recent history. The following land use data is defined on the basis of irrigated acres, or aerial extent. The predominant KRWCA crop in 1990, from the DWR crop database (DWR, 2014), was cotton, accounting for about 236,000 irrigated acres (over one third of irrigated acres). Cotton, field crops (small grains, hay and forage), alfalfa, and truck crops (vegetables, melons and berries) made up almost 80 percent of the cropped irrigated acreage; however, almond, grape, and citrus were also significant individual crops at this time.

For 2013, the spatial crop database was acquired from the Kern County Agricultural Commissioner, which defines land use (County of Kern Agriculture and Measurement Standards, 2014). This land use data is defined as commodity acres, which includes multiple counting of double and triple cropped irrigated acres. The total cropped commodity acreage within the primary boundary was 806,000 commodity acres. Currently 466,347 irrigated acres are single-cropped while 152,894 irrigated acres are multi-cropped. Cotton acreage fell to approximately 38,000 acres in 2013 (less than 20 percent of its acreage in 1990). In contrast, almond and pistachio acreage increased from 62,000 to 162,000 acres and 3,000 to 44,000 acres, respectively. Corn also increased from 6,000 acres to 40,000 acres, replacing some of the alfalfa acreage, and much of the range and pasture acreage, which fell from 4,000 to 400 acres. See **Figure 10** and **Figure 11** for a review of the KRWCA historical (1990) and current (2013) cropping distribution, respectively.

Some generalizations may be made on the types of soils that are used to grow different crop types. Within the KRWCA primary boundary, most citrus is grown along the eastern side, or Foothills region, where soils are medium-textured. The Foothills regional topography also creates microclimates with fewer incidences of freezing temperatures, which is more conducive to citrus. Mountain and foothill areas in the northeastern part of the KRWCA boundary are used as rangeland for cattle or sheep and are primarily non-irrigated. Crops such as dryland wheat may be grown in this area. Grapes are also typically grown on coarse or medium-textured soils found in the northeastern portion of the KRWCA primary area and in the southern area corresponding to the Kern Fan. In contrast, the heavy (fine-textured) soils of the Clay Rim region are dominated by crops such as cotton, wheat, corn and tomatoes. In general, permanent crops have expanded onto various types of soils that were previously not used to grow trees and vines. Corn and silage has also expanded on various soil types in response to livestock feed demand, primarily in proximity to dairy developments. See Section 2 in the KRWCA GAR for additional analysis.

2.1.2 Soils

The primary area of the KRWCA can be divided into five main areas relative to soil texture and typical cropping: the Clay Rim, Foothills, Kern Fan, Northern Areas, and Wheeler Ridge/Arvin Edison regions

(**Figure 12**). Soil pH is generally higher in the southern and northwestern areas of the primary KRWCA area. These areas roughly correspond to alluvium from the San Emigdio Mountains and fringes of alluvial fans. High salinity is typical of historic lakebed, swamp and overflow, and alluvial fan margin soils; the combination of high pH and high salinity is found in many of those areas.

The Clay Rim region accounts for approximately 154,000 gross acres in the KRWCA's primary boundary, and consists of heavy (fine-textured) soils extending from the mid-northwestern boundary of the focus area southerly to the southern tip. It includes the historic Buena Vista Lake Bed and historic Kern Lake Bed, derived from lacustrine deposits, and historic swamp and overflow lands at the margins of alluvial fans and historic lake beds.

The Foothills region represents about 63,000 gross acres, and consists of medium-textured soils extending along the eastern edge of the focus area.

The Kern Fan region, representing approximately 225,000 gross acres, includes soil derived from river deposition. Because of their alluvial origins, soil texture varies with the distance from the mouth of the historic drainage coming from the foothills, but can generally be characterized as coarse-textured.

The Northern Areas region, representing approximately 330,000 gross acres, is generally comprised of soils that are less easily characterized and divergent in texture.

The Wheeler Ridge/Arvin-Edison region encompasses approximately 198,000 gross acres and generally has coarse-textured soils. The region boundary generally follows the Arvin-Edison Water Storage District (**AEWSD**) and Wheeler Ridge-Maricopa Water Storage District (**WRMWSD**) borders, with some exceptions. A portion of northeastern AEWSD has been included in the Foothills region, as it is more consistent with that area in terms of cropping and soils. Similarly, because of differences in soil texture and crop type in the northern part of WRMWSD, the northern portion is included in the Clay Rim region

Historic lake beds, swamps, and overflow lands consist of slightly acidic lacustrine and alluvial fan margin soils that are formed when fine particles settle out from lake and swamp water. The Kern and Buena Vista historic lake beds are comprised of clay soils with little variation. In particular, the Buena Vista lakebed, though it has silty clay soils at the surface, is underlain by a very thick horizon of clay soil with very low permeability. Surface soils typically have a relatively high saturation percentage (60 percent to 80 percent), meaning that they hold relatively large amounts of water compared to coarser-textured soils with large pores that drain water more readily.

2.1.3 Geology

2.1.3.1 Regional Stratigraphy

Surficial regional geology is shown on **Figure 13** (USGS 2014) and key elements of the geologic and hydrogeologic setting are summarized below. The primary portion of the KRWCA area is located almost entirely in the areas mapped as very recent or recent alluvium, and the entire contiguous portion of this area is on the floor of the San Joaquin Valley.

A geologic map showing recent deposits (Page 1986) is presented on **Figure 14** showing more detail of the Neogene and Holocene (late Tertiary and younger) basin sediments that comprise the majority of the contiguous primary portion of the KRWCA area. These basin sediments are rimmed by Tertiary and pre-Tertiary bedrock to the east, south, and west. The Kern River bisects the area and it is underlain by recent channel deposits. The morphology of the recent alluvial fan is indicated by the trajectory of the canal systems south of the river. The terminus of the ancestral river occurred at inland lakes including the historical Kern Lake and Buena Vista Lake beds, shown on the map. During long periods of large flows, the river drained north to the Tulare Lake Bed. These paleo-drainages are associated with the deposition of fine-grained sediments, shown on the map as flood-basin deposits and older lacustrine deposits. There are small areas east of the San Joaquin Valley near Stallion Springs and Tehachapi that are also included in the KRWCA primary area.

The mapped geology in the secondary portion of the KRWCA area indicates a wide range of materials and depositional environments. Nearly 80 percent of this area is mapped as igneous and metamorphic materials that likely have no primary porosity. The remaining 20 percent of the secondary area is equally distributed between older lithified sedimentary material and recent alluvial, glacial, or landslide deposits.

2.1.4 Hydrogeology

The groundwater hydrology of the KRWCA area is considered notable within the TLHR due to the groundwater basin configuration, hydrologic stresses, and depth to first-encountered groundwater. As noted in the expert report submitted to the Central Valley Regional Water Quality Control Board (**CVRWQCB**), these unique aspects represent spatial disconnects throughout the KRWCA area which may potentially complicate the groundwater monitoring required by the General Order (Gailey 2013). There is very little information regarding groundwater conditions in the secondary portion of the KRWCA. This is especially true of groundwater level information as there are few groundwater level measurements available and no assessment of regional groundwater patterns has been completed.

2.1.4.1 Groundwater Basins and Subbasins

The primary portion of the KRWCA area includes parts of four DWR designated basins:

- The Kern County Portion of the San Joaquin Groundwater Basin (Kern County Subbasin, No. 5-22.14);
- The Cummings Valley Groundwater Basin (No. 5-27);
- The Tehachapi Valley West Groundwater Basin (No. 5-28); and,
- The Brite Valley Groundwater Basin (No. 5-80).

The locations of these groundwater basins are shown on **Figure 15**.

The majority of the primary portion of the KRWCA area is within the Kern County Subbasin, which is the southern-most portion of the San Joaquin Valley Groundwater Basin, as defined by DWR. The Kern County Subbasin is included in the CVHM. The USGS generally used the DWR delineations of groundwater basins in the Central Valley in the development of the active area of the CVHM.

2.1.4.2 General Groundwater Chemistry

The primary portion of the KRWCA area includes the majority of the Kern County Subbasin of the San Joaquin Groundwater Basin, which is an inland groundwater basin with no significant outflow. Because of this, salts generally tend to increase in concentration over time in groundwater, which contributes to increasing salinity and TDS concentrations (KCWA 2012). Shallow zones in the eastern subbasin are primarily characterized as containing calcium bicarbonates and increasing in sodium with depth. This trend shifts from east to west, with west side water primarily containing sodium sulfate to calcium-sodium sulfate. Shallow groundwater in the western region is characterized by high TDS, sodium chloride, and sulfate which is problematic for agricultural uses. Arsenic levels in groundwater are often associated with lakebed deposits (DWR 2003).

2.1.4.3 Water Bearing and Discharge/Recharge Zones

It is estimated that groundwater accounts for approximately 39 percent of total water supply in the region; however, during dry years it can increase to as much as 60 percent. The main groundwater basin in the region is the San Joaquin Valley groundwater basin (Kern Subbasin, 5-22.14). Other groundwater basins in the region include small, sporadic basins located throughout the foothills in the region. The assessment of subsurface sediments has focused on the Kern County Subbasin, as the majority of the primary portion of the KRWCA area overlies this aquifer. As outlined by the DWR, the Kern Subbasin water bearing zones are generally comprised of sediments deposited during the Tertiary and Quaternary age. These formations include:

- Olcese Formation: primarily sand, ranging from 100 - 450 feet (**ft**) thick, supplies drinking water in the northeastern portion of Kern County where the formation occurs as a confined aquifer;
- Santa Margarita Formation: coarse sand, ranging from 200 - 600 ft thick, supplies drinking water in the northeastern portion of Kern County where the formation occurs as a confined aquifer;
- Tulare Formation: comprised of clays, sands, and gravels, up to 2,200 ft thick, derived from the Coastal Range, moderately to highly permeable and yielding moderate to large water quantities, includes the Corcoran Clay Member;
- Kern River Formation: includes poorly sorted lenticular clay, silt, sand, and gravel derived from the Sierra Nevada, ranging from 500 – 2,000 ft thick, moderately to highly permeable and yielding moderate to large water quantities, includes the Corcoran Clay Member;
- Older Alluvium/Stream and Terrace Deposits: loosely consolidated lenticular deposits of clay, silt, sand, and gravel, 250 ft thick, yielding large water quantities; and,
- Younger Alluvium/Flood Basin Deposits: stratified and discontinuous clay, silt, sand, and gravel beds, up to 150 ft thick, permeability varies with fine grained percentage, as with deposits underlying historic Buena Vista and Kern Lakes (DWR 2003).

The shallow groundwater areas identified and mapped by the Kern County Water Agency (**KCWA**) roughly correlate to areas of low permeability soils in and around the Buena Vista and Kern Lake beds in the southern portion of the Subbasin, and within the western portion of the Semitropic Water Storage District. The KCWA has been tracking the presence of these shallow groundwater areas since 1976, and the extent of the area has generally increased over that period (KCWA, 2011). While the shallow groundwater areas are contoured separately from the unconfined aquifer, there is no indication that shallow groundwater is actually a completely separate and distinct water body.

The thickness of the unsaturated zone varies over time and space in the Kern County Subbasin. These changes in unsaturated zone thickness occur in response to temporal and geographic variation in managed groundwater recharge and groundwater extractions.

Groundwater recharge is the sum of the hydrogeologic processes by which water percolates into a groundwater aquifer, a function of available water and permeable ground surfaces. Recharge areas are a "primary" net benefit to water quantity, and high source water quality may provide a "secondary" net benefit by diluting the concentrations of groundwater constituents. Major groundwater recharge sources in the KRWCA area generally have lower concentrations of nitrate and salinity than the receiving groundwater aquifer. However, minor recharge sources may have higher concentrations of nitrates and salinity, and could negatively impact groundwater quality.

Natural recharge, a function of precipitation, ET, and soil moisture holding capacity, is limited in the primary area and cannot be estimated for the secondary area.

Agricultural return flow is the water that runs off crop land and/or percolates past the root zone in excess of the crop needs, or root zone water holding capacity. Agricultural return flow is primarily a function of irrigation efficiency, effective precipitation, and management. Kimmelshue and Tillman (2013) estimated the total return flow for 21 crop, soil, and irrigation method scenarios, representing the majority of cropping systems in the Kern Subbasin.

Municipal return flow results from precipitation and water applied to the ground surface in municipal settings that exceeds evaporation, consumptive use, and root zone water holding capacity, or percolation from stormwater detention basins. In Bakersfield (considering both City and Cal Water systems combined), the estimated return flow over the period from 2006 through 2010 was 9,100 acre-feet per year (**AFY**) over a combined service area of 65,587 acres, or 0.14 AFY per acre (**AFY/ac**).

Treated wastewater is regulated by the CVRWQCB under specific individual WDRs and waste discharge permits. Recharge from septic systems is significant in the KRWCA, but is not measured or estimated. Recharge from wastewater generated by food processing, confined animal facilities, and other industries may also be significant, but are generally regulated under WDRs.

Enhanced recharge and banking is performed in the area by multiple water agencies through various mechanisms, including canal seepage as water is conveyed, recharge ponds, and seepage from reservoirs. In-lieu recharge activities that displace groundwater use by providing surface water in-lieu of pumping groundwater are also a significant recharge management practice in the region. Canal seepage is generally of high quality, and managed recharge is considered to have an overall positive benefit to groundwater quality in the KRWCA area. There are a number of enhanced groundwater recharge projects in the KRWCA area. Additional analysis and mapping of these projects is presented in Section 8 of the KRWCA GAR.

2.1.4.4 Water Sources and Water Chemistry

The water bearing zones which supply domestic, irrigation, and municipal beneficial uses vary throughout the KRWCA region. Typically domestic wells will utilize shallower groundwater aquifers due to the cost of drilling deeper wells, but there is no comprehensive record for domestic well depth ranges. Due to their shallower depths, domestic wells typically experience groundwater quality issues associated with surface level activities, specifically nitrates and 1,2-dibromo-3-chloropropane (**DBCP**).

Municipal and agricultural wells have been estimated by the DWR to be drilled to depths exceeding 2,000 ft. Currently, agricultural irrigation wells are being drilled through all usable water bearing zones. The usability of the water tends to decrease with depth as the TDS increases, especially with the presence of connate water, but there is no consistent depth or trend associated with this phenomenon. Municipal wells are drilled and screened based on site specific factors, including the presence of nitrate and DBCP in the shallow water bearing zones, or the presence of arsenic and radionucleides at variable depths. Arsenic is present in many San Joaquin Valley formations, but is only present in groundwater under specific geochemical conditions. Sediments throughout the KRWCA may contain radionucleides, but it is highly variable and must be defined on an individual site. Due to this variability, municipal wells are not necessarily shallower than agricultural wells (Herb Simmons, Provost & Pritchard, personal communication, 15 December 2014).

2.1.4.5 Aquifer Characteristics

Based on annual spring groundwater elevation contours prepared by KCWA for 2000 through 2013 (KCWA 2014), the highest groundwater elevations in the period were in the spring of 2007 (wet period) and the lowest occurred in the spring of 2013 (dry period). The 2007 wet period unconfined aquifer depth to groundwater ranges from less than 50 ft below ground surface (**bgs**) to over 700 ft bgs. The deepest groundwater depths occur in the southern portion of the KRWCA primary area. The 2013 dry period depth to water contours are similar but show that groundwater is generally 30 to 80 ft lower. Groundwater elevations in 2007 were highest near the Kern River and the associated groundwater banking operations. The lowest groundwater elevations during this period are in the northwest portion of the Subbasin.

A groundwater elevation surface to represent changes from drought conditions was found by subtracting the spring 2012 surface from the spring 2013 surface, and on average groundwater elevations within the KRWCA primary area decreased over 34 ft. The highest magnitude reductions in groundwater elevations during this period occurred along the eastern edge of the Subbasin. Between 2005 and 2006, a wet period, groundwater elevation changes ranged between increases of over 120 ft to decreases of nearly 140 ft, with an average increase of over 13 ft. The dominant groundwater elevation trends in the area are the large variations near the Kern River on the Kern Fan produced by the high volumes of managed recharge and recovery associated with groundwater banking projects. These effects dissipate away from the Kern Fan, where groundwater elevation patterns are more muted and show seasonal effects, short term responses to wet and dry periods, and long term groundwater declines.

Given the significant variations in groundwater elevations that occur throughout the Kern Subbasin in response to variations in hydrologic conditions, no single groundwater elevation surface should be taken to be representative of groundwater flow directions. Therefore, a combined groundwater elevation surface was generated to represent trends in groundwater elevation and flow directions throughout the Subbasin, found on **Figure 16**. These flow directions show that average groundwater flow north of the Kern River is generally towards the north and center of the Subbasin, focused on low average elevations in the north.

2.2 Identification of Constituent of Concern (COC) Source

2.2.1 Irrigated Agriculture

Nitrate migration to groundwater occurs with deep percolating water as it travels through the unsaturated zone (deep percolation). As such, in irrigated agriculture, the application of water and the method of irrigation is a key factor influencing nitrate impacts. Some deep percolation is required to allow salts to be leached away from the root zone, which is necessary to sustain agricultural production. Irrigation efficiency and nutrient management can help to minimize nitrate impacts, but they cannot be completely avoided due to salt leaching requirements.

2.2.2 Alternative Sources

Nitrate can also be found in groundwater as a result of percolation from feedlots or dairies, food processing facility discharges, or from wastewater. Approximately 39,200 irrigated acres of the KRWCA area falls under the regulatory coverage of the CVRWQCB Waste Discharge Requirements General Order for Existing Milk Cow Dairies (Order R5-2013-0122) (**Dairy General Order**). It is unknown how many acres within the KRWCA boundary are under the regulatory jurisdiction of other WDR's or conditional waivers of WDR's (i.e. effluent wastewater, food processing, recycled water, etc). Historical dairy facilities were determined by reviewing the Kern County Planning Department Dairy List (County of Kern, 2005) and cross checking the facilities to historical 1995 aerial photography (**Figure 17**). Current dairy facilities were determined by a spatial dataset based on 2012 Dairy General Order program monitoring of all reported dairy facility and associated crop acreages provided by the CVRWQCB (CVRWQCB, 2012). The 2012 spatial dataset was crosschecked to 2012 aerial photography to ensure dairy facility and dairy crop accuracy.

2.2.3 Source Identification Study

The KRWCA will not be pursuing a source identification study for any areas of nitrate exceedance within the primary region. Previous efforts to define the relative contribution of various nitrate producing activities to groundwater impacts have yielded inconclusive results, especially in defining or explaining legacy impacts. As such, the cost and effort required to thoroughly conduct an identification study is considered to have little benefit.

2.3 Beneficial Uses

The CVRWQCB Water Quality Control Plan for the Tulare Lake Basin (**Tulare Lake Basin Plan**) designates groundwater aquifer beneficial uses to be protected, water quality objectives to protect those beneficial uses, and a program of implementation needed for achieving or sustaining these objectives. The four DWR groundwater basins included in the area of the KRWCA, noted previously, are designated for municipal (**MUN**), agricultural (**AGR**) and industrial (**IND**) beneficial uses (CVRWQCB, 2004).

A Basin Plan amendment for regions throughout the Tulare Lake Basin is currently being pursued by the Central Valley Salinity Alternatives for Long-Term Sustainability (**CV-SALTS**), which may result in a de-designation of some groundwater areas from MUN. An exception to the MUN designation can be made when TDS exceeds 3,000 mg/L, contamination cannot reasonably be treated, there is insufficient water supply, or the water source is regulated as a geothermal energy source (CVRWQCB, 2004). The latter three criteria can qualify an exception to AGR designation, and the latter two to IND classification. These criteria may apply to Buena Vista and Kern Lake areas.

2.4 Management Practices Baseline

The NHI and its extensive background research (Letey et al., 1979; Plant Nutrient Management Technical Advisory Committee, 1994; and Wu et al, 2005) provide a baseline evaluation of agricultural system management decisions which can be protective of groundwater quality through minimizing the potential for nitrate leaching. The NHI focuses on the main contributors to nitrate leaching potential that interact in land-use decisions at the surface: soil type, crop type, and irrigation type. The NHI factors fertigation practices and deep ripping within the hazard values assigned to soil, crop, and irrigation types.

Implementation of the NHI ranking provides a clear and direct tool to introduce nitrate leaching potential to members throughout the KRWCA area. Analysis of the interaction of these factors provides a foundational baseline for the implementation of reasonable management practices to reduce nitrate leaching risk.

2.4.1 Existing Practices

Spatial irrigation data is presented on **Figure 18**. Overall, permanent crops are increasing significantly in the region and in nearly all cases are developed with highly efficient drip and/or micro spray irrigation systems. This corresponding increase in highly efficient irrigation systems on permanent crops (e.g. almonds, pistachios, grapes, etc.) is somewhat similar in other counties, however is most prevalent in Kern County. For example, by 2012, 91 percent of almonds were irrigated with drip or micro-sprinkler irrigation systems in Kern County, compared to 82 percent and 83 percent of almonds in Tulare and Fresno counties, respectively. Similar trends exist in citrus and grapes. For example, in 2012, 91 percent of grapes were irrigated with drip or micro-sprinkler systems in Kern County, compared to 63 percent in Fresno County and 77 percent in Tulare County (Kimmelshue and Tillman, 2013). This is likely due to the scarcity and expense of water, as well as a dynamic and recent change to permanent crops in Kern County. Pressurized irrigation systems are also increasing on annual crops such as tomatoes because they can save water and increase yield due to their ability to closely match ET, minimizing plant water stress, and deliver nutrients through fertigation more efficiently.

Fertigation is common in drip, micro-sprinkler, and impact head sprinkler irrigation systems. For example, most vegetables on drip and sprinkler systems are fertigated (Nunez, personal communication, 2014). It is also used in surface irrigation systems, such as on the Buena Vista Lake Bed where some, but not all, fertilizer may be injected into the irrigation water. In this case, the fertilizer source is close to the field so that fertilizer travel time in the irrigation water is reduced. Because excess water in these systems is either captured in tile drains or collected in tail water, and returned to the irrigation system, excess fertilizer contained in this water is also recycled to the irrigation system.

2.5 Available Groundwater Data

2.5.1 Data Sources

The data employed to analyze the groundwater quality exceedances for the purpose of the GAR was collected and compiled into a comprehensive groundwater quality database. The sources of groundwater quality data available for this study are:

- State Water Resources Control Board Division of Drinking Water [**SWRCB-DDW**, formerly California Department of Public Health (**CDPH**)] [through the Groundwater Ambient Monitoring & Assessment Program (**GAMA**)];
- CDPH Archived Data;
- DWR;
- Cleanup Sites (EDF) (through the GAMA program);
- KCWA;
- DPR CDPH (through the GAMA program);
- USGS (through the GAMA program);

- CVRWQCB Waste Discharge Requirements General Order for Existing Milk Cow Dairies (Order R5-2013-0122) Monitoring Data.

The resulting database includes over 145,000 records for the three constituents of focus (nitrate, total dissolved solids, and pesticides) from over 6,700 locations. These groundwater quality data represent available results from 1909 through 2014. Well construction information is not generally available for the wells for which groundwater quality data are available. As a result, the analyses presented in the CGQMP and GAR does not include any evaluation of depth or aquifer material associated with groundwater quality results. As noted, it is assumed for the sake of this evaluation that all groundwater quality results represent first encountered groundwater. Some of the available groundwater quality data was associated with wells for which location information was not available; therefore, these data were not included in the analyses.

3 Management Plan Strategy

The focus of the KRWCA management plan relies on the understanding and acceptance that surface conditions and activities dictate the degree of nitrate leaching below the root zone of the crop. To effectively address the surface level decisions that influence nitrate leaching, a clear understanding of the nature of nitrate transport, the requirements of a range of agricultural management systems, and the factors which influence management choices is required. The KRWCA will not exclusively rely on contaminant loading, fate and transport modeling, or groundwater quality trends to validate the protective nature of specific management practices. Due to the nature of nitrate as a non-point source contaminant, large knowledge gaps, and inadequate data, it is infeasible to retroactively trace local nitrate impacts back to specific agricultural management system choices. Similar barriers exist in tracing the impacts of newly implemented practices and their nitrate impact on groundwater due to the spatial and temporal disconnects prevalent throughout the KRWCA.

As such, management plan implementation will focus efforts on addressing irrigation and nutrient management practices through extensive outreach and education for all irrigated lands included in the scope of the CGQMP. The outreach will also address multiple surface level metrics, including the NHI and the nitrogen applied/removed (**A/R**) ratio, to help growers gauge the impact of agricultural system management decisions on farms and their potential impact on groundwater quality. See **Section 4** for a further description of the A/R ratio. Additional collaborative research will be required to improve the available data, particularly for estimating nitrogen removal, required for identifying nutrient ratios for a variety of agricultural systems.

3.1 Approach and Prioritization

To facilitate and focus groundwater quality monitoring and agricultural system management efforts, all identified KRWCA HVAs were prioritized. Priority values were calculated throughout the identified HVA to define a three tier system of high (Tier I), medium (Tier II), and low (Tier III) priorities. The KRWCA HVA prioritization framework considers the proximity of high vulnerability lands to public and disadvantaged community (**DAC**) groundwater supply wells, a multiplicative overlay and index evaluation of relative hydrogeologic (intrinsic) sensitivity, and the NHI. **Figure 19** provides a flowchart of the various prioritization parameters, the scenarios for each parameter, and the points applied to each respective scenario. For each identified HVA field, the respective upgradient of public water supply well scenario, relative hydrogeologic sensitivity scenario, and NHI scenario was determined. Scenario points were added together to arrive at an HVA field prioritization score (an additive overlay and index approach), as illustrated by mapping on **Figure 20** and the prioritization scenario table shown in **Table 2**.

3.1.1 Nitrogen Groundwater Pollution Hazard Index (NHI) Risk Categorization

The KRWCA NHI results indicate that certain crop systems consistently fell into the higher nitrate leaching risk category. The following key cropping scenarios are examples of the agricultural systems that may be considered higher risk in the finalized NHI categorization (in order of acreage):

i. Silage corn on sprinkler or surface irrigation on medium to coarse-textured soils;

ii. Field crops (wheat) with surface irrigation on medium or light-textured soils;

iii. Potato on sprinkler or surface irrigation; and,

iv. Truck crops and vegetables.

Crops that have relatively low nitrate leaching risk due to low NHI scores include:

- Alfalfa;
- Perennials with high efficiency irrigation;
- Pasture; and,
- Processing tomatoes.

Though some permanent crops such as almonds are high nitrate users, they are predominantly irrigated with drip irrigation, which results in a lower nitrate leaching risk rating for those crops. Alfalfa is a high water user and has significant acreage in the KRWCA, but because alfalfa is a legume and fixes its own nitrogen from the atmosphere, it is not a priority in nitrate leaching risk management. Processing tomatoes are largely drip-irrigated in the KRWCA, yielding a low NHI score, and also have relatively low acreage, resulting in a low priority designation.

3.1.2 High Vulnerability Area (HVA) Prioritization Results

The KRWCA HVA analysis identified 7 crops comprising more than 80 percent of the HVA (in order of acreage): almonds, truck crops, grapes, potatoes, field crops, cotton, and corn. The HVA prioritization analysis, as described above, identified the same crops (save grapes) comprising 91% of the Tier I category. In order of acreage, these are:

- Almonds;
- Truck crops;
- Field crops;
- Potatoes;
- Corn; and,
- Cotton.

Within the Tier I prioritization category, three irrigation types were identified (in order of acreage): surface, sprinkler/surface, and sprinkler.

It is important to note that the entire agricultural management system needs to be considered when analyzing the prioritization results, and that irrigation system type has a significant impact on the resulting prioritization tier. For example, all of the almond acres identified as Tier I in the prioritization analysis are irrigated with surface irrigation systems while all of the acres identified as Tier III are irrigated with drip, sprinkler, or drip/sprinkler irrigation systems. This correlation between irrigation system type and resulting prioritization tier is common for most of the crops identified in the KRWCA HVA. Surface irrigation methods are more prevalent in Tier I and Tier II (a limited amount of pressurized irrigation methods are also included in Tier II), while pressurized irrigation methods are more prevalent in Tier III. **Table 3**, **Table 4,** and **Table 5** summarize KRWCA prioritization tiers by crop and irrigation type for Tiers I, II, and III, respectively.

3.2 Actions Taken

There has been extensive research on California agricultural management practices, particularly for irrigation and nutrient management, including publications such as Nitrogen Source Reduction to Protect Groundwater Quality (Dzurella et al., 2012). The KRWCA, along with other coalitions, will attempt to unify formerly conducted research, best practices, and current knowledge to determine realistic time frames for implementation, decipher where data gaps truly exist, and assess the barriers to implementation in a variety of scenarios. This effort is particularly necessary because, generally, the data required to determine A/R ratios, as well as the impacts of specific management practices, is not currently available.

After establishing the relevance of previously conducted research and the barriers to implementation, outreach and education will be designed to address these barriers and provide the requisite knowledge to improve irrigation and nutrient management and facilitate pump and fertilize practices. Further research will undoubtedly be required to fill in the data gaps which may further hinder implementation or limit efficacy of practices in different crop types. The A/R ratio will be defined on a management unit-specific basis as a self evaluation and a tracking tool for member participation and a gauge of the implementation of new management practices.

Groundwater monitoring will be standardized through the Groundwater Quality Trend Monitoring Program to further satisfy the need for trend analysis, although, as noted in Gailey 2013 and the State Water Resources Control Board Agricultural Expert Panel (**SWRCB-AEP**), trends must be evaluated over a multi-year basis and may not be representative of current practices.

3.2.1 Member Education to Maintain and Improve Water Quality

Outreach and education efforts will focus on the integration of research relevant to nutrient and irrigation management. Additional education efforts will elaborate on the opportunities to mitigate and remediate current nitrate contamination through techniques including, but not limited to, pump and fertilize (Harter et al 2012).

3.2.2 Management Practices Identification, Validation, and Implementation

The KRWCA intends to conduct a thorough literature review of current knowledge pertaining to efficient irrigation and nutrient management practices, particularly as they relate to priority crops and scenarios. Despite noted data gaps, there is currently a body of work with which to develop effective and relevant outreach and education materials. University of California Cooperative Extension and commodity group resources and assistance will be instrumental in this effort.

There is no one-size-fits-all combination of management practices to protect groundwater quality that can account for the dynamic interactions observed across the extensive range of cropping scenarios and agricultural system characteristics. Individual cropping scenarios will necessarily require different combinations of agricultural system management practices to optimize protection of groundwater quality in the most cost effective and efficient manner. A great deal of research and theory has been compiled on California agricultural irrigation and nutrient management. A review of relevant knowledge is likely sufficient to initially identify practices to suggest for implementation and to formulate effective outreach and education materials.

For instance, Dzurella et al (2012) provides numerous practices, compiled for California agriculture, that decrease or potentially decrease nitrogen (**N**) leaching. While these practices may be promising, the specific decrease in nitrate leaching or increase in nitrogen uptake efficiency is not currently quantified. These resources will be employed to develop outreach and education materials to challenge growers to improve nitrogenous fertilizer application efficiency and irrigation efficiency. Ultimately, the success of outreach and education is dependent on application customized to a specific cropping system, most likely through certified nutrient management plans and site specific irrigation management plans. Much of the work of tailoring improvements must necessarily be done by those who are most familiar with all of the details of the respective cropping scenarios; namely, growers and their consultants. Validation of achieved improvements is planned to ultimately come from the A/R ratio, once requisite data gaps have been filled.

3.2.2.1 Management Practices Evaluation Program (MPEP)

As specified in the General Order, the purpose of the MPEP is to determine the effects, if any, irrigated agricultural practices may have on first encountered groundwater under different conditions that could affect the discharge of waste from irrigated lands to groundwater (e.g., soil type, depth to groundwater, irrigation practice, crop type, nutrient management practice). Therefore, the MPEP can theoretically help provide validation of groundwater protection for new or existing practices.

Overall, the objective of the MPEP, to establish a direct relationship between the nitrogen mass balance and nitrate discharge beneath the root zone, as related to specific representative management practices, is extremely difficult to achieve. In defining nitrate discharge beneath the root zone, numerous scientific studies corroborate the difficulty of tracking nitrogen as well as the error in extrapolating nitrate leaching between sites. Additionally, particular management practices may contribute to theoretically good irrigation and nutrient management, but overall the interaction of the practices with one another is what influences nitrate leaching. As such, it is the position of the KRWCA that implementing practices which are protective of groundwater quality requires good overall irrigation and nutrient management, which considers how the practices work in concert with one another, under the particular field circumstances.

3.3 Duties and Responsibilities

3.3.1 Identification of Project Administration

Nicole Bell is the current KRWCA ILRP Program Manager and will be responsible for administering the Comprehensive Groundwater Quality Management Plan. The KRWCA Board may change project administration duties from time to time.

3.3.2 Individual Responsibilities

An initial evaluation of potential KRWCA partners includes organizations and programs which have missions that prioritize the implementation of effective nutrient and irrigation management. Although these organizations are well suited to working in conjunction with the KRWCA and have been actively involved in aspects of the Long-Term Irrigated Lands Regulatory Program (**ILRP**), there have been no formal agreements to collaborate in implementation efforts.

3.3.3 Organizational Chart

The Comprehensive Groundwater Quality Management Plan Organizational Chart is included as **Figure 21**.

3.4 Implementation Strategy

3.4.1 Partner Agencies and Entities

The KRWCA will compile background information for management practices, facilitate training programs, and produce outreach and educational materials appropriate to various aspects of farm management and growers that are involved in the identified priority cropping scenarios. Partners available to support development of these resources include, but are not limited to:

- California Department of Food and Agriculture (**CDFA**);
- Fertilizer Research and Education Program (**FREP**);
- Kern County Agricultural Commissioner;
- Natural Resources Conservation Service (**NRCS**);
- Cal Poly Irrigation Training and Research Center (**ITRC**);
- University of California Cooperative Extension (**UCCE**); and,
- Cooperating coalitions and the Southern San Joaquin Valley Water Quality Coalition (**SSJVWQC**).

Additional research objectives will likely be achieved in partnership with commodity groups that are dedicated to providing access to information on effective field level management practices to improve production and efficiency. Resources and consultation provided by the American Society of Agronomy Certified Crop Advisors (**ASA-CCAs**) and the Irrigation Association will also be employed throughout regional implementation of nutrient management plans and evaluation of irrigation management.

The missions of programs such as the UCCE, ITRC, and FREP position them as optimal partner organizations to help accomplish the objectives of the CGQMP. Existing training programs and outreach materials developed by the UCCE, ITRC, and FREP will be employed to the greatest extent possible. This will prevent redundant efforts by the KRWCA while strengthening the impact and network of the existing programs.

3.4.2 Protective Management Practices

To define a specific management practice, or set of management practices, as protective of groundwater is an over simplification of the hydrology, hydrogeology, and the myriad of interacting physical and biological systems within any given agricultural management system. There is no benefit in prescribing management practices as inherently protective in isolation of the unique context of an irrigated agricultural management system at the field level. Quite possibly, the prescription of particular practices may contribute to an increase in nitrate leaching potential if growers are required to adopt practices which may not be relevant to their unique context.

As such the role of the KRWCA is to facilitate the execution of effective irrigation and nutrient management plans. Comprehensive plans will take into account the impact of management practices within the full context of individual agricultural management systems, accounting for farm operations and physical factors. The KRWCA will also focus on irrigation and nutrient management tools which may improve the implementation of effective irrigation and nutrient management plans. This will include integrating, promoting, and training with tools and methods such as the California Irrigation Management Information System (**CIMIS**), ET tracking, and irrigation scheduling. The KRWCA will incorporate and disseminate new information on promising practices as it becomes available from the MPEP or other sources. Finally, improvement in long term A/R ratios will provide a metric that indicates systems which are cumulatively beneficial.

3.4.2.1 Technically and Economically Feasible Practices

As described previously, the proven effectiveness of a given management practice can vary between nearly identical cropping systems. Technically and economically feasible practices should be prioritized by cropping scenarios defined as having a high nitrate leaching potential. The practices outlined by research specific to California agriculture, such as those outlined by Dzurella et. al (2012), define an initial starting point for identifying practices applicable to these priority cropping systems. Technically and economically feasible practices cannot be defined outside of the context of a cropping system, so it is beyond the scope of current knowledge and does not yield itself to a summary list.

3.4.2.2 Practice Effectiveness and Limitations

Generally, practices do not have an associated quantifiable decrease in nitrate loading to groundwater, so the absolute protectiveness or effectiveness of a given management decision generally cannot be calculated without extensive time, effort, and funding. This can be seen in the long term investigation undertaken in the Woodstock Study where the effects of changing agricultural management practices on nitrate concentrations in groundwater needed for municipal uses were examined (Haslauer et al., 2004; Tracy, 2014). Quantifying changes in nitrate leaching as a direct result of changes in management is a complex study and may take more resources than are available at this time. If a reduction in N leaching can indeed be quantified for a particular practice, it would be site specific and may or may not apply to other sites.

The general limitation, as defined, is the impossibility of completely eliminating the potential to leach nitrate. Practice effectiveness is also limited by correct implementation of the management practices; although effective outreach and education will seek to mitigate incorrect implementation, management errors may still occur.

3.4.3 Outreach Strategy

Outreach events will focus on providing resources to members and improving practices associated with irrigation and nutrient management. Outreach events are planned to occur twice yearly and will include presentations of applicable information from resources evaluated or created by the KRWCA. Irrigation management and nutrient management trainings will be organized by the KRWCA in partnership with the UCCE, NRCS, CDFA, commodity groups, or Kern County Agricultural Commissioner to educate growers in efficient and effective management practices. Additional outreach efforts will extend resources required for mitigation endeavors, including pump and fertilize methods, which requires knowledge of the nitrate content of irrigation water sources and how the nitrogen can be used to meet crop needs and offset other fertilizer application. The KRWCA will also assist in efforts by members to receive nutrient management plan self certification.

3.4.4 Management Practices Implementation Schedule

3.4.4.1 Timetable to Identify Management Practices

The identification of management practices is dependent on the compilation of comprehensive resources for California agriculture and the subsequent evaluation within high priority cropping scenarios. Realistic timetables for the analysis of protective practices relevant to unique cropping scenarios will be determined after the requisite literature review and consultation with the UCCE, NRCS, CDFA, commodity groups, and Kern County Agricultural Commissioner. As discussed, initial analyses of relevant practices are available for consideration and can be presented within the first year.

3.4.4.2 Timetable for Management Practices Implementation

Some practices may be able to be adopted as soon as 2 to 3 years from the initial notification of high vulnerability status and subsequent outreach and education. Other practices may be linked to the timeline of the MPEP, funding opportunities, and the completion of relevant training.

3.4.5 Performance Goals

Considering the noted limitations, the efficient application of nitrogen and irrigation water is considered a primary performance goal. Implementing effective management must take into account the economic and technical barriers inherent in changes to existing agricultural management systems. Baseline performance data for A/R ratios will need to be developed before relevant performance goals can be set.

3.4.5.1 Targets/Expected Progress

The significance of the potential changes in management practices cannot be neglected, especially in terms of cost, and assuming an unrealistic timeline for implementation poses an additional barrier to compliance and fulfilling the goals of the ILRP. From a scientific perspective, given the physical setting and parameters, significant improvement in groundwater quality may take decades to achieve (Harter 2012). Even once improvements are made at the surface it can take decades before groundwater quality changes are observed at depth. Additionally, fluctuations in groundwater quality, including degradation or improvement, may still indicate legacy impacts.

4 Monitoring Methods

4.1 Measure Achievement of CGQMP Goals

4.1.1 Compliance Rates

To evaluate the compliance rates of members to implement practices protective of groundwater the KRWCA proposes to employ a metric recommended by the SWRCB-AEP, the A/R ratio. The A/R ratio evaluates the approximate nitrogen use efficiency, and indirectly provides feedback on irrigation efficiency, as a favorable A/R ratio is less likely to be achieved with poor irrigation efficiencies.

$$\frac{A}{R} = \frac{Nitrogen\ Applied}{(Nitrogen\ removed\ at\ harvest) + (Nitrogen\ sequestered\ in\ the\ permanent\ wood\ of\ perennial\ crops)}$$

Multi-year averages of A/R ratios provide a method to evaluate the shift in agricultural management practices at the farm level. The distribution of A/R ratio averages for all KRWCA members provides a tool to educate growers on achievable nitrogen management to motivate self-regulation. A lower A/R ratio represents a more efficient cropping system. A/R ratios would begin to be evaluated after extensive education and development of a basis for estimating N removed.

Currently there is very little data on ranges of A/R ratio values, but it is an appropriate and beneficial area of research for commodity groups and associated research groups. Research and intimate knowledge of on-farm systems will be required to define achievable A/R ratios, which includes estimating the nitrogen removed for various crops. It may not be possible to set strict A/R ratios for compliance, particularly with the use of organic nitrogen and its availability over time. However, as the SWRCB-AEP pointed out, long term averages will help factor out such sources of variability and assess overall compliance.

Feedback on compliance will be summarized from additional data provided by members in accordance with the Nitrogen Management Plan Summary Reports and the Farm Evaluation, which will provide statistics on adoption of other promoted practices.

4.2 Measure Effectiveness of CGQMP Practices

4.2.1 Groundwater Improvement

Compliance cannot be gauged by direct measurement of nitrate discharge beneath the root zone from irrigated lands, particularly from year to year (SWRCB-AEP). Improving the efficiency of irrigation can lead to increased nitrate concentrations in deep percolation, and depending on mixing, at first encountered groundwater. As such the recommended trend monitoring will be long term, with multi-year values as recommended by the SWRCB-AEP.

4.2.1.1 Groundwater Quality Trend Monitoring Program

The intent of the Groundwater Quality Trend Monitoring Program is to evaluate long-term groundwater quality trends. As extensively documented, due to the disconnection between surface practices and effects to groundwater quality at depth, the KRWCA region is uniquely unsuited to representative groundwater monitoring to indicate the benefit or detriment caused by specific agricultural management system practices. The KRWCA presents a unique hydrogeological system of spatial and temporal disconnects caused by the average thickness of the unsaturated zone as well as the extensive managed recharge and extraction operations influencing groundwater flow trends (Gailey 2013). As such, only a general evaluation of the regional impact of irrigated agriculture is possible.

4.3 Additional Monitoring Required to Validate Management Practices

The KRWCA does not plan to institute any additional monitoring at this time.

5 Data Evaluation and Reporting

After implementation of nutrient and irrigation management plans, and after relevant data gaps have been filled, A/R ratios will be collected annually and values will populate a long term data set for summarization and interpretation. Averaging A/R ratios over time for KRWCA members provides a representative distribution of varying practices throughout the KRWCA primary area. The analysis and resulting distribution will be shared with growers through outreach events to educate members on regional A/R ratios. This information will be included in the Management Plan Status Report, due as of May 1st every year, for the review of the CVRWQCB.

Figures and Tables

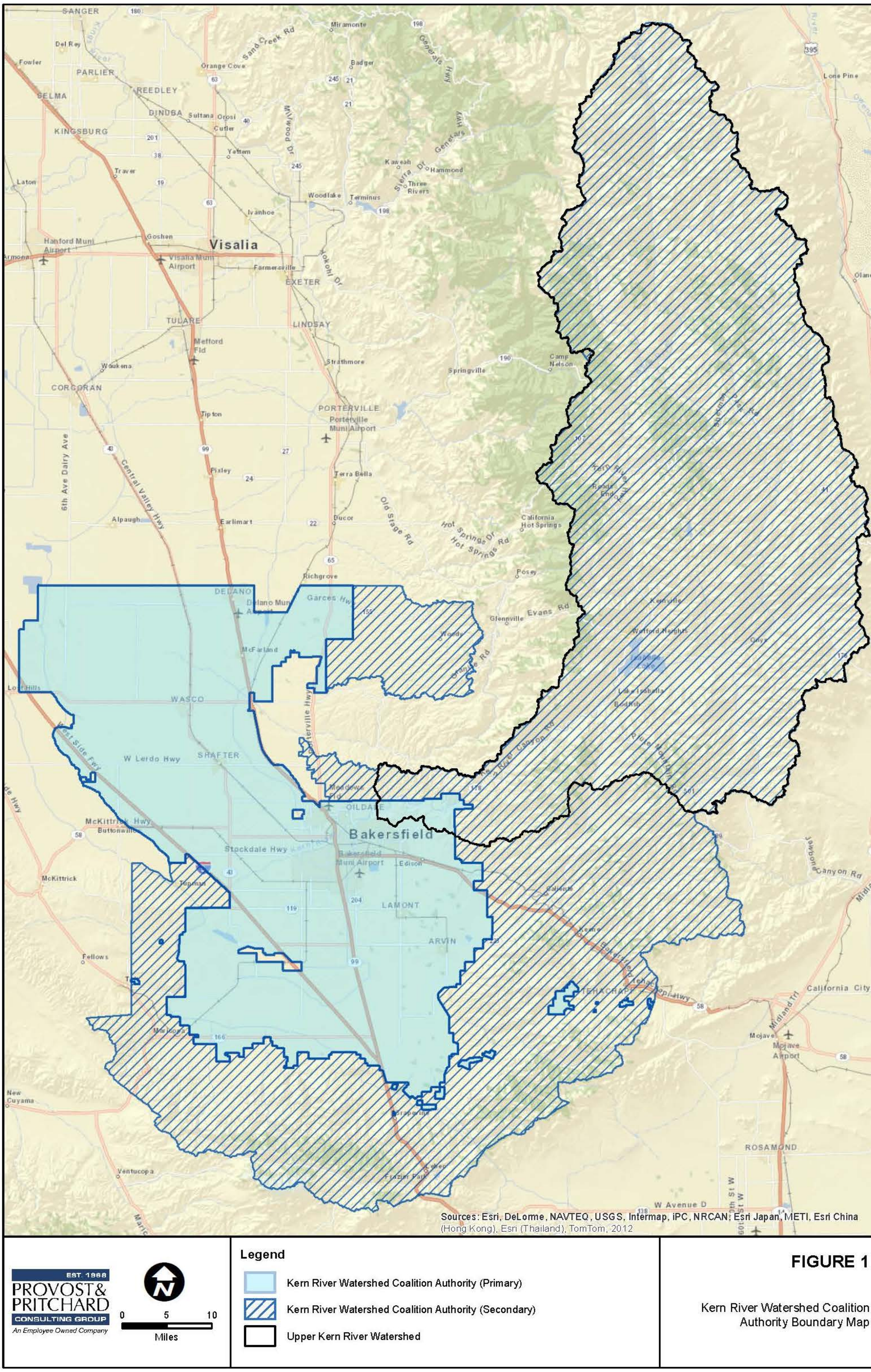


Figure 1. Kern River Watershed Coalition Authority Boundary

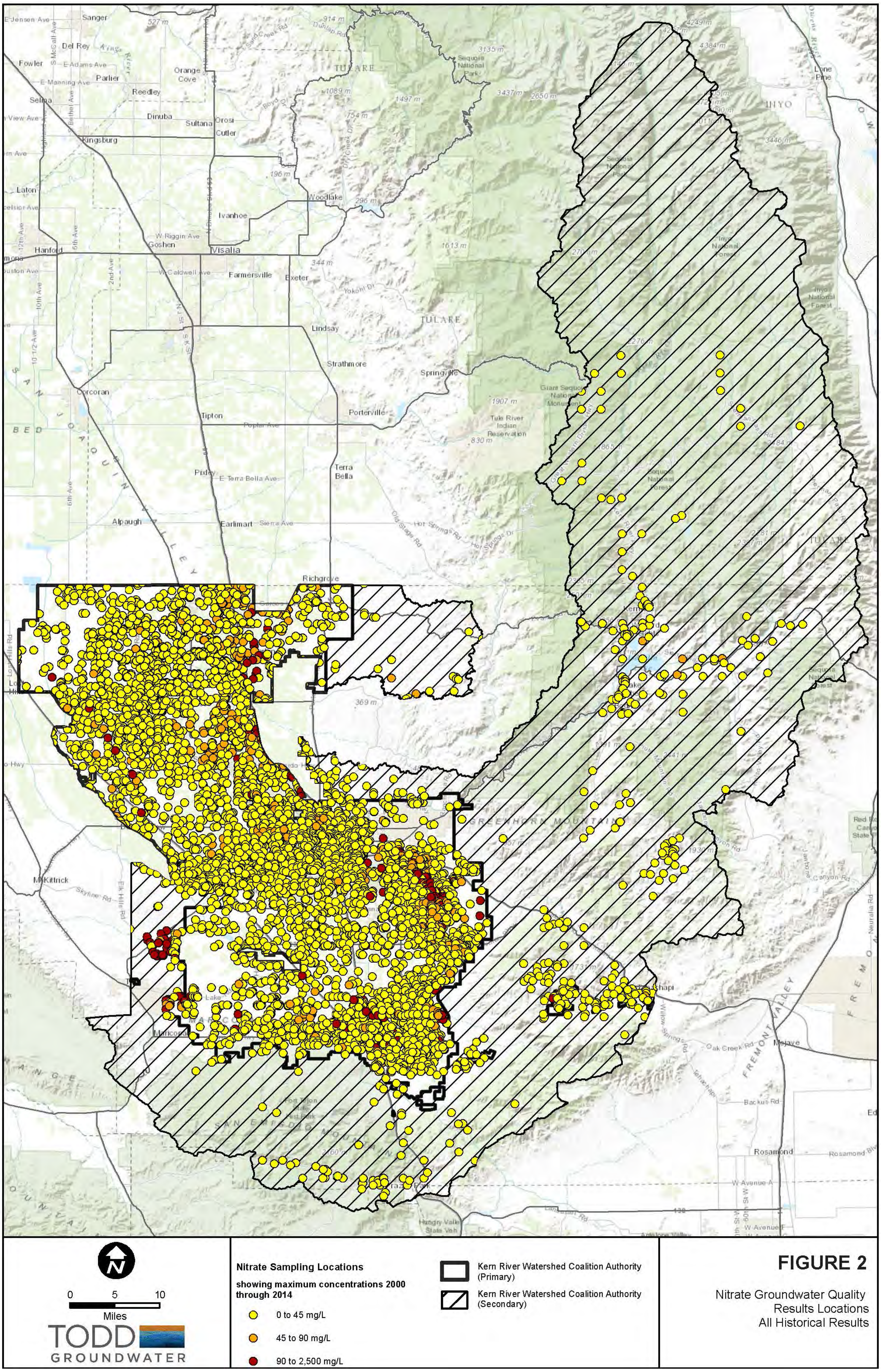


Figure 2. Nitrate Groundwater Quality Results Locations, All Historical Result

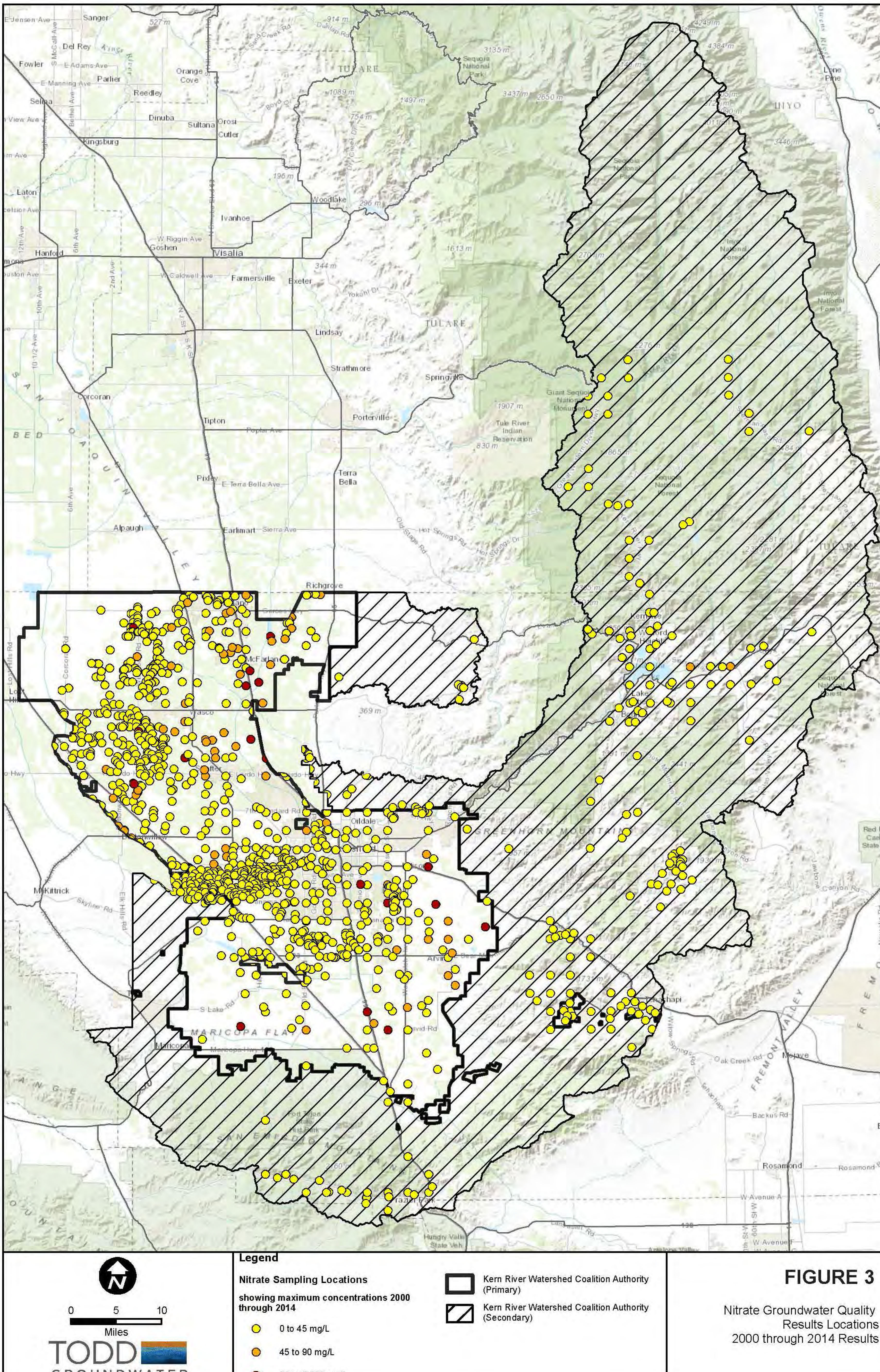


Figure 3. Nitrate Groundwater Quality Results Locations, 2000 through 2014 Results

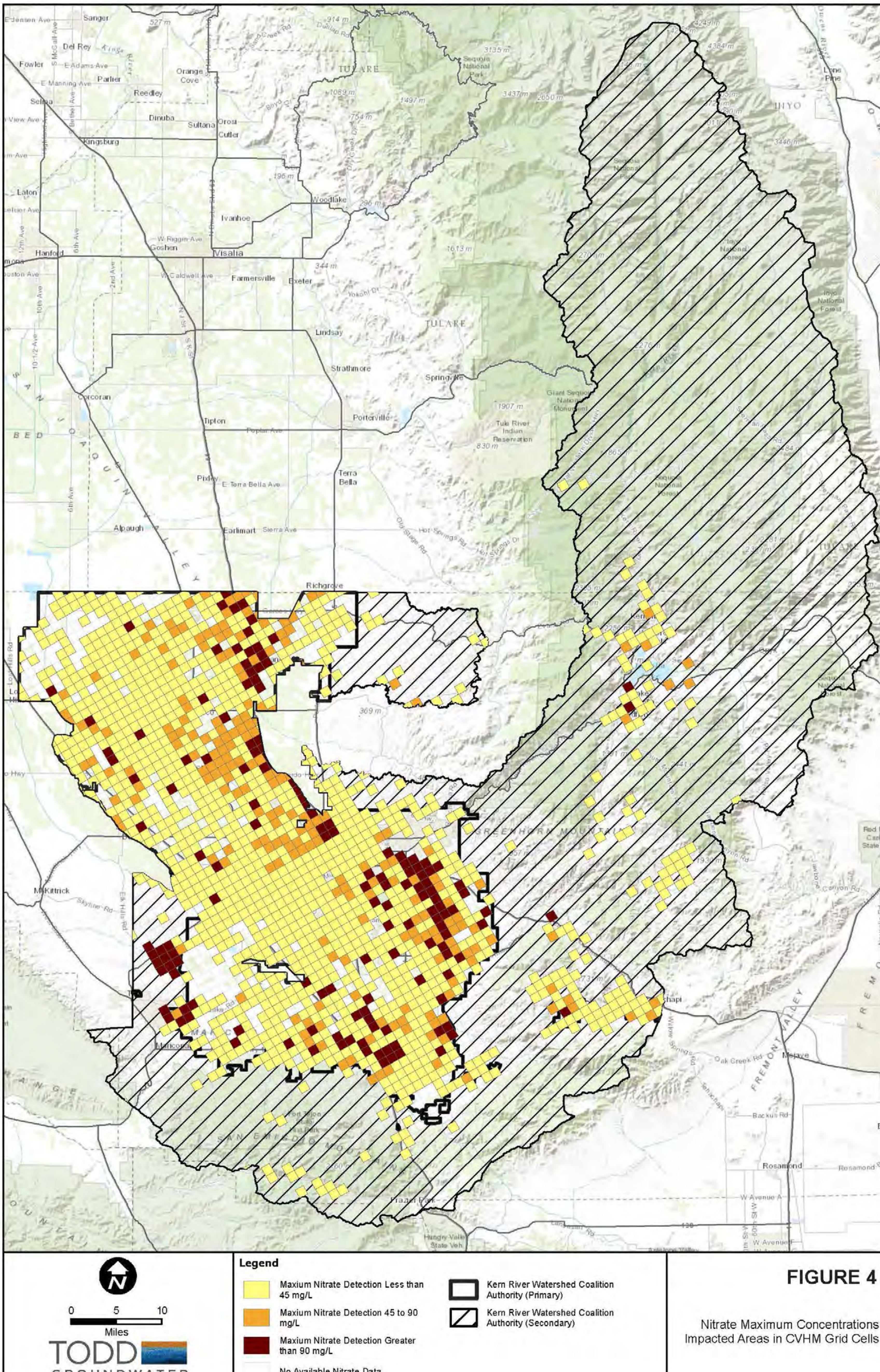
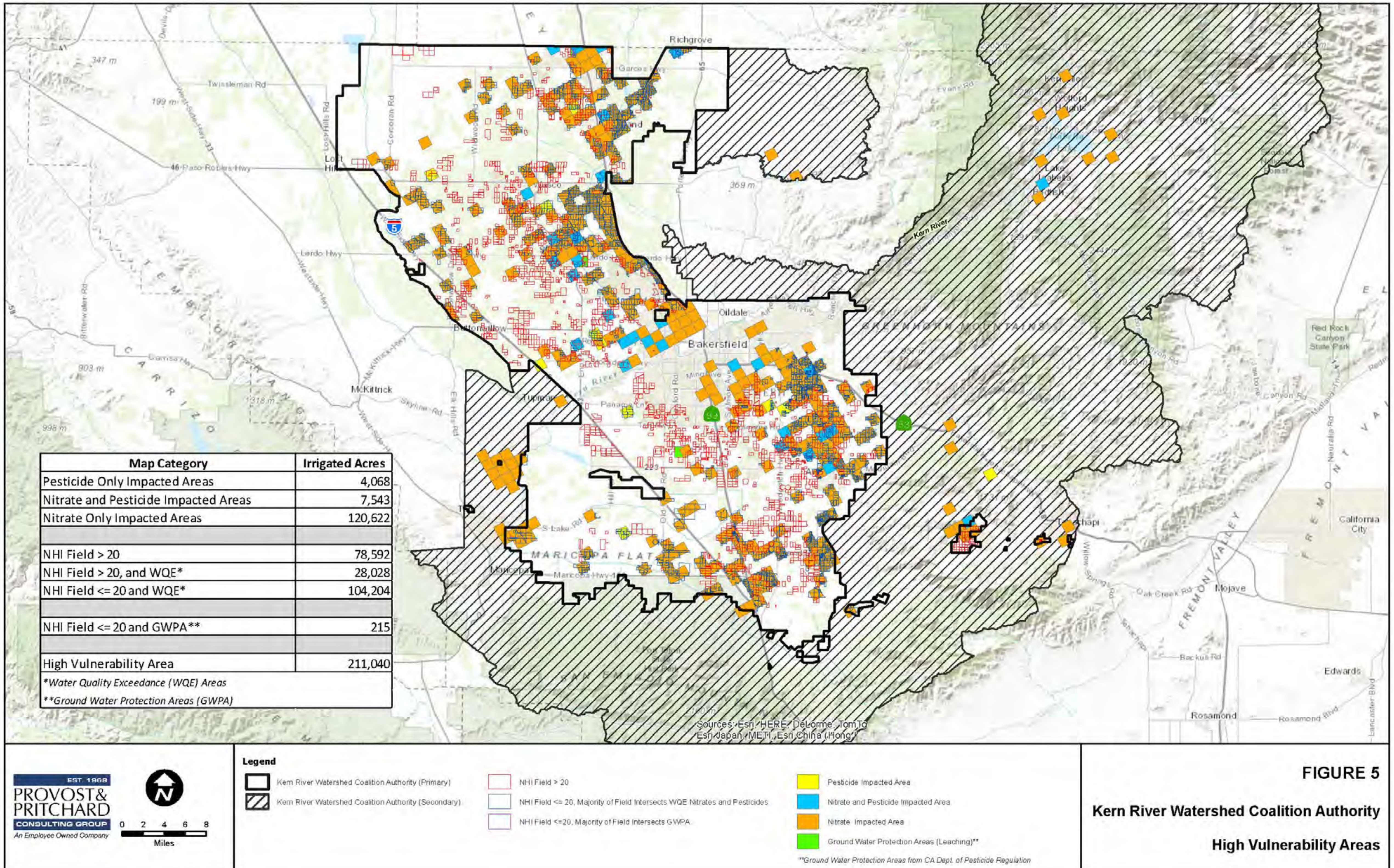


Figure 4. Nitrate Maximum Concentrations, Impacted Area in CVHM Grid Cells



Map Category	Irrigated Acres
Pesticide Only Impacted Areas	4,068
Nitrate and Pesticide Impacted Areas	7,543
Nitrate Only Impacted Areas	120,622
NHI Field > 20	78,592
NHI Field > 20, and WQE*	28,028
NHI Field <= 20 and WQE*	104,204
NHI Field <= 20 and GWPA**	215
High Vulnerability Area	211,040

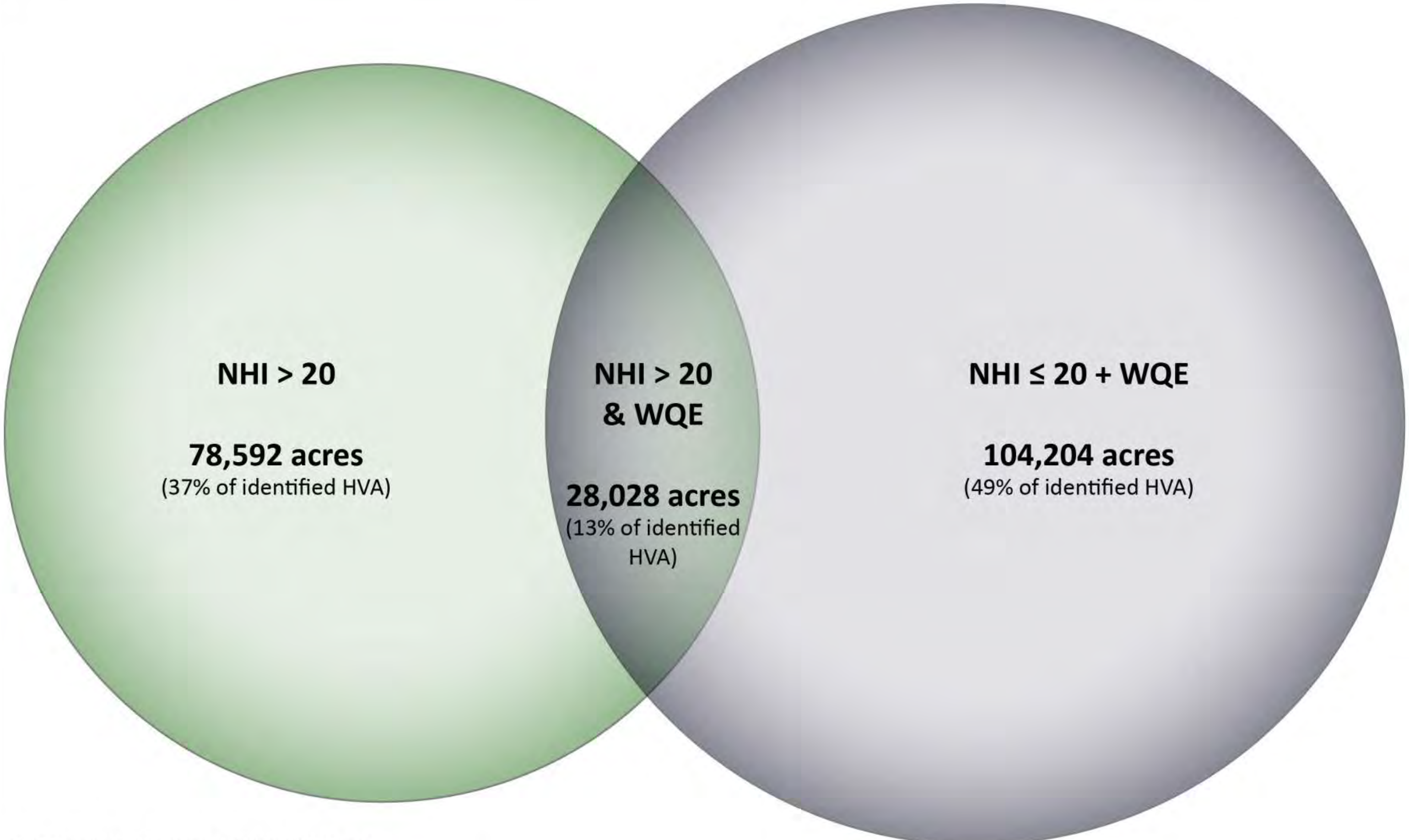
**Water Quality Exceedance (WQE) Areas*
***Ground Water Protection Areas (GWPA)*

Figure 5. KRWCA High Vulnerability Area

Table 1. KRWCA High Vulnerability Area by Identification Scenario

KRWCA High Vulnerability Area by Identification Scenario		
KRWCA HVA Identification Scenario	**Irrigated Acres (ac)**	**Percent of HVA (%)**
NHI Field Score > 20	78,592	37.2%
NHI Field Score > 20 & WQE	28,028	13.3%
NHI Field Score ≤ 20 & WQE	104,204	49.4%
DPR GWPA (Leaching)	215	0.1%
Total HVA:	**211,040**	**100.0%**

KRWCA: Kern River Watershed Coalition Authority
HVA: High Vulnerability Area
WQE: Water Quality Objective Exceedance
DPR: California Department of Pesticide Regulation
GWPA: Groundwater Protection Area



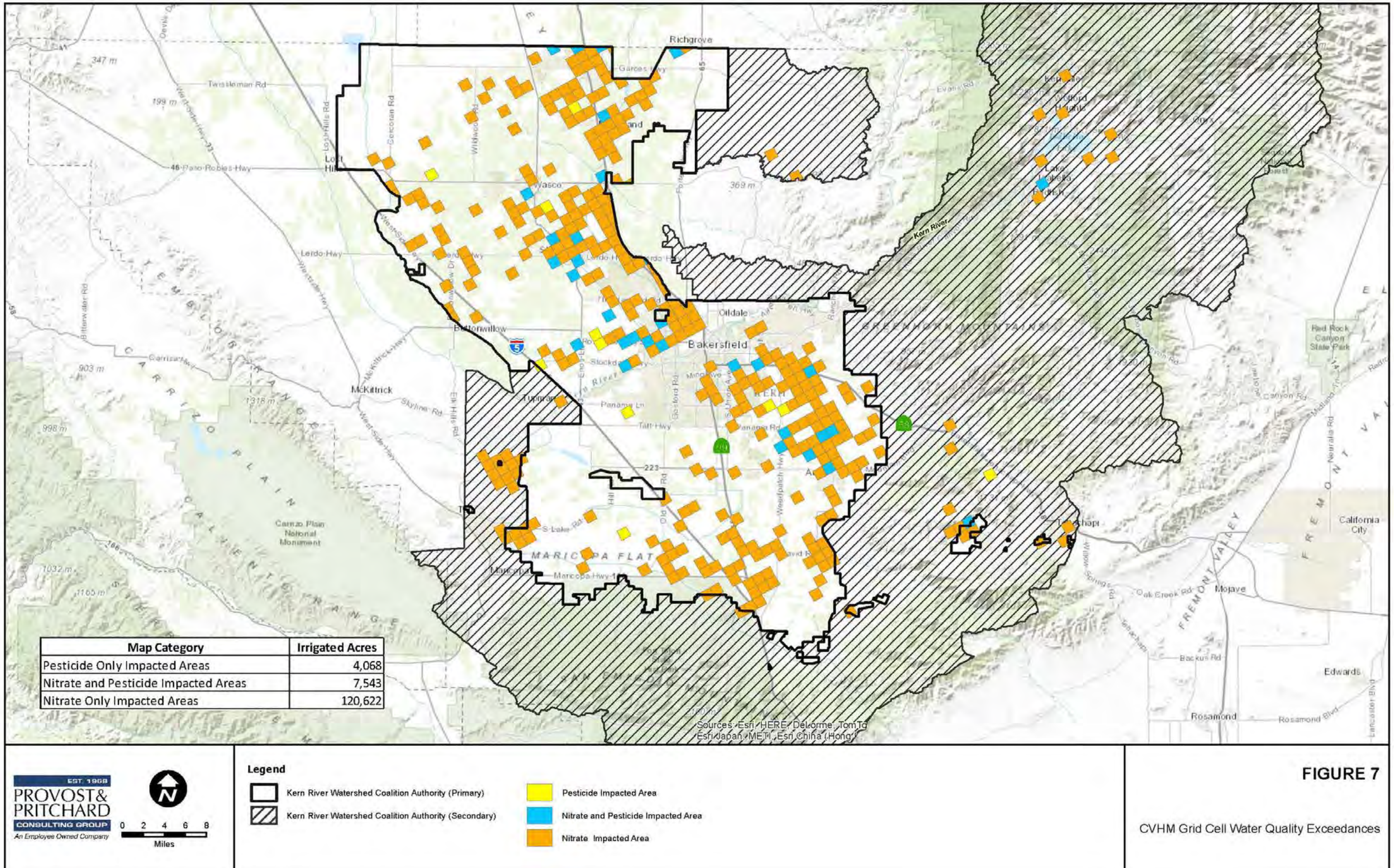
NHI: Nitrate Groundwater Pollution Hazard Index

WQE: Water Quality Objective Exceedance (Nitrate and/or Pesticides)

HVA: High Vulnerability Area

Note: Acreages provided are irrigated acres.

Figure 6. KRWCA NHI and Water Quality Exceedance HVA Venn Diagram



Map Category	Irrigated Acres
Pesticide Only Impacted Areas	4,068
Nitrate and Pesticide Impacted Areas	7,543
Nitrate Only Impacted Areas	120,622

Figure 7. Areas Exceeding Water Quality Objective

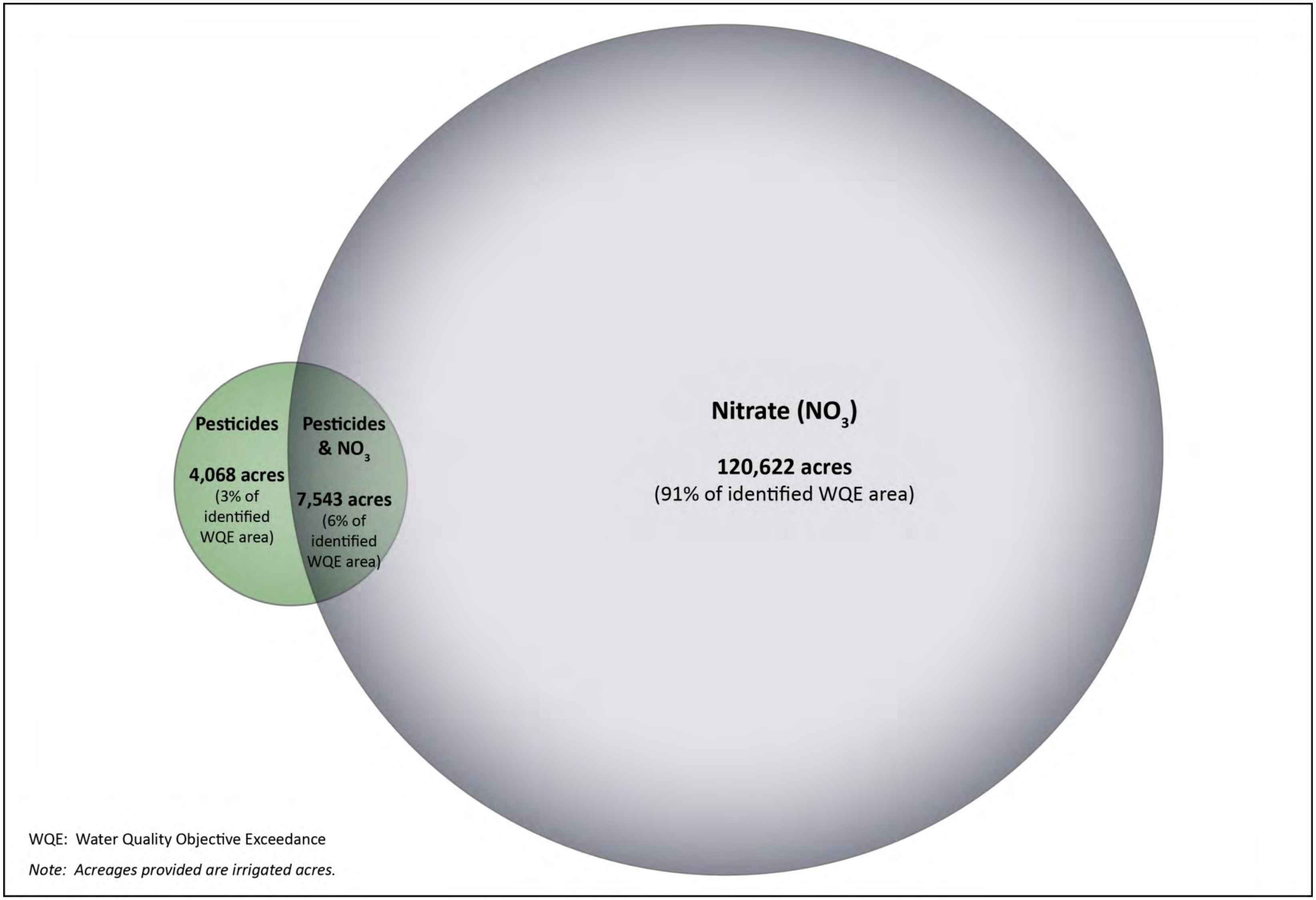


Figure 8. KRWCA Pesticides and Nitrates Water Quality Exceedance Venn Diagram

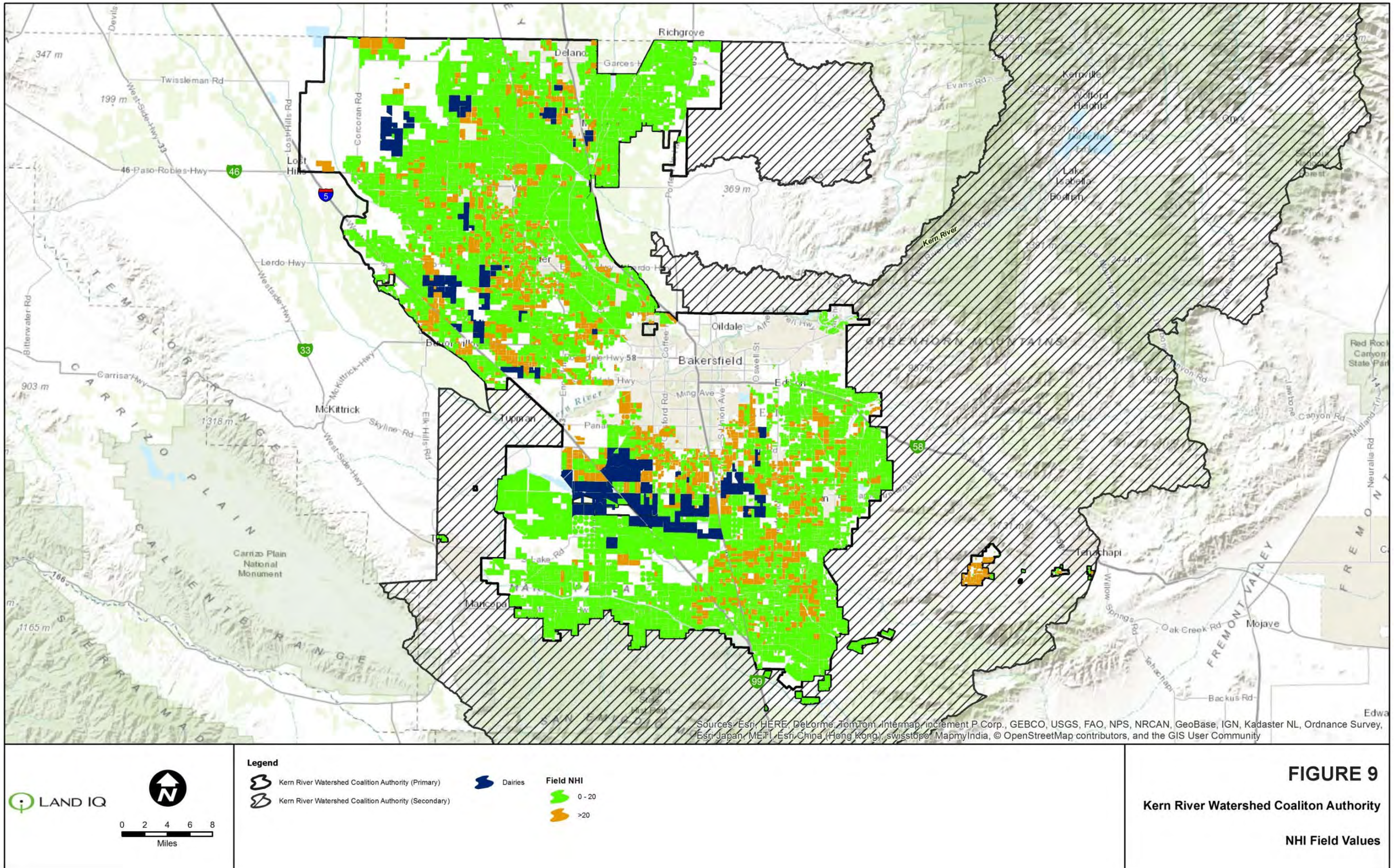


Figure 9. KRWCA NHI Field Values – 2013

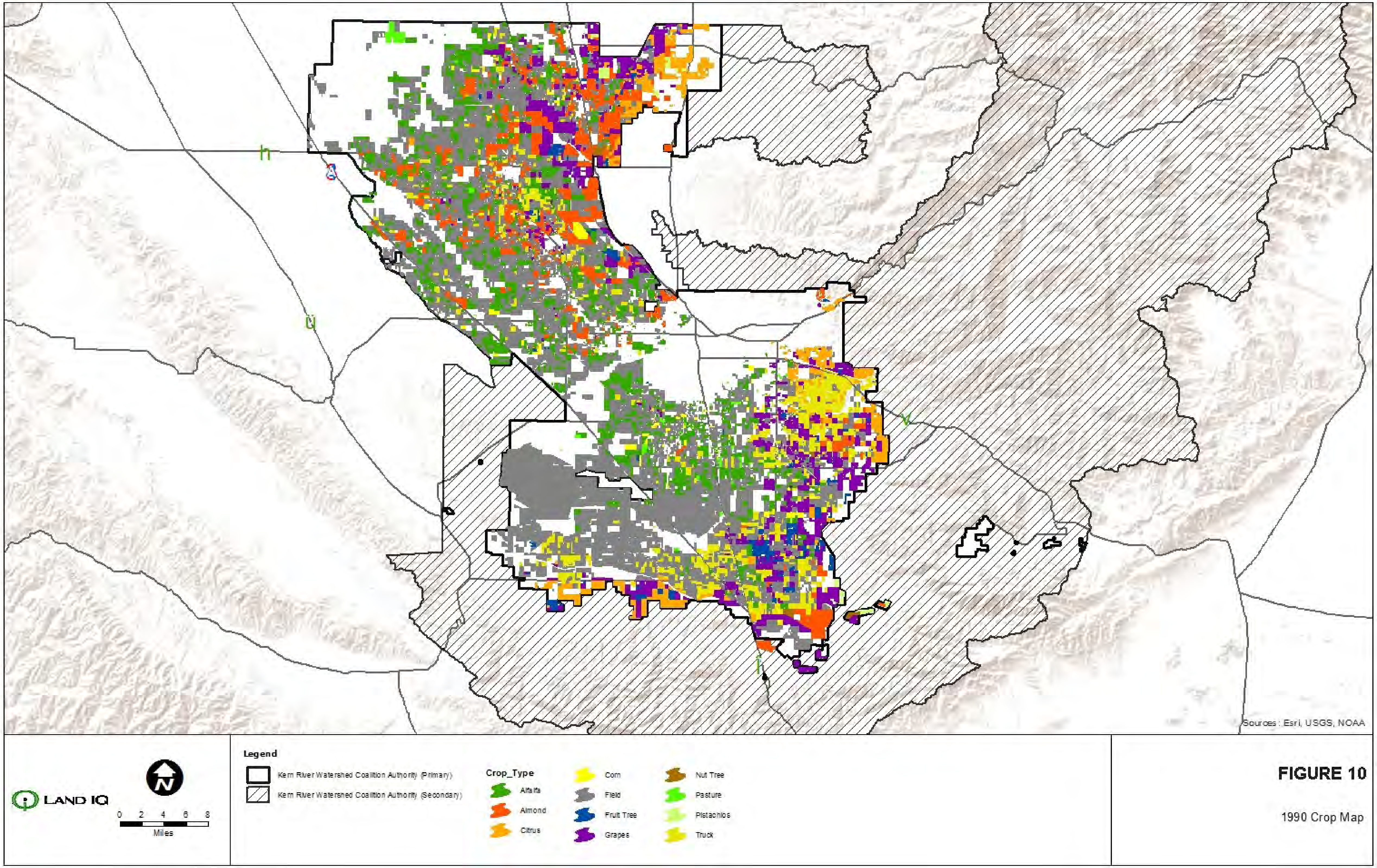


Figure 10. 1990 Distribution of Crop Types in KRWCA

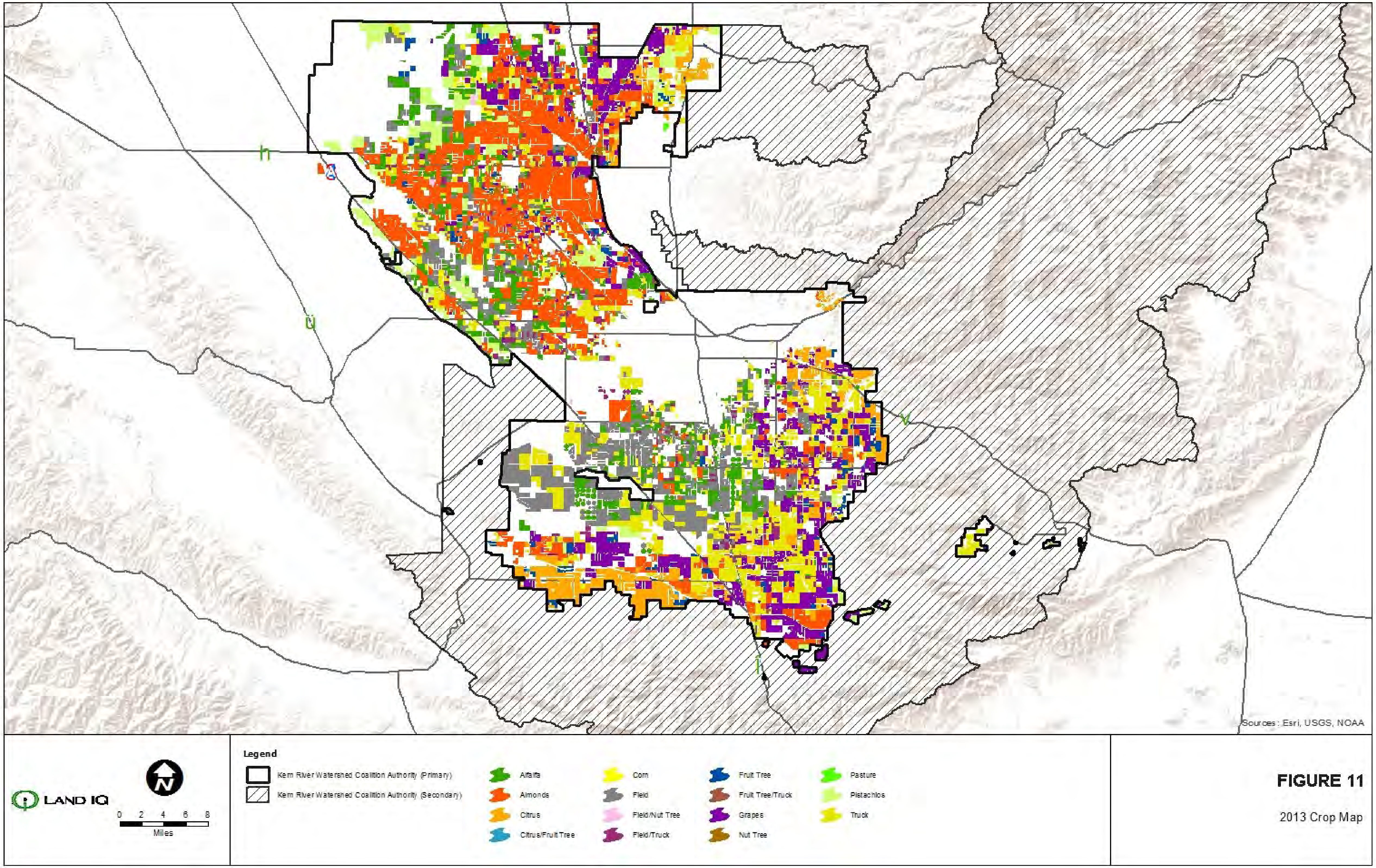
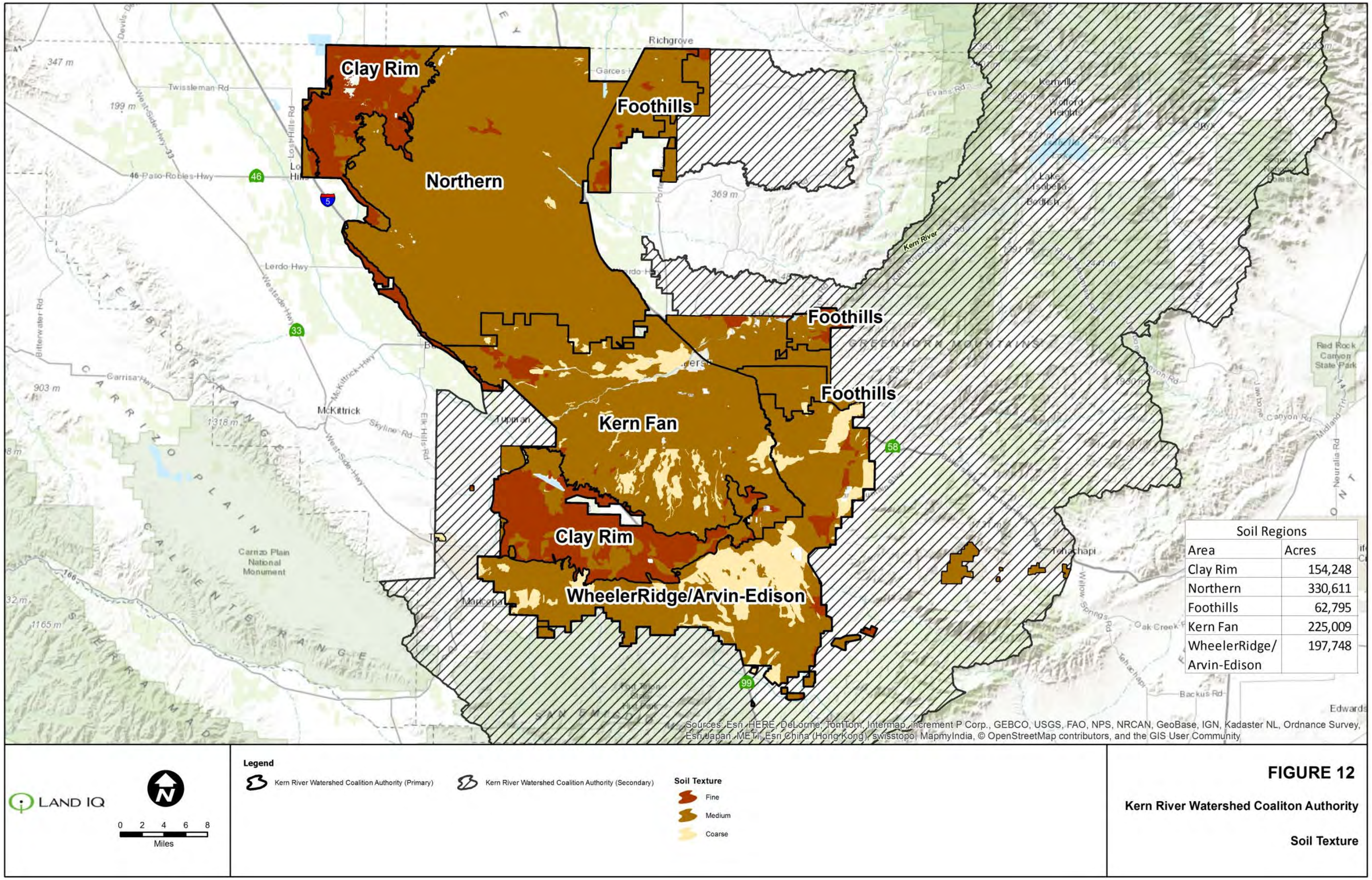


Figure 11. 2013 Distribution of Crop Types in KRWCA



Soil Regions

Area	Acres
Clay Rim	154,248
Northern	330,611
Foothills	62,795
Kern Fan	225,009
WheelerRidge/ Arvin-Edison	197,748

Figure 12. KRWCA Primary Boundary Generalized Soil Texture Map

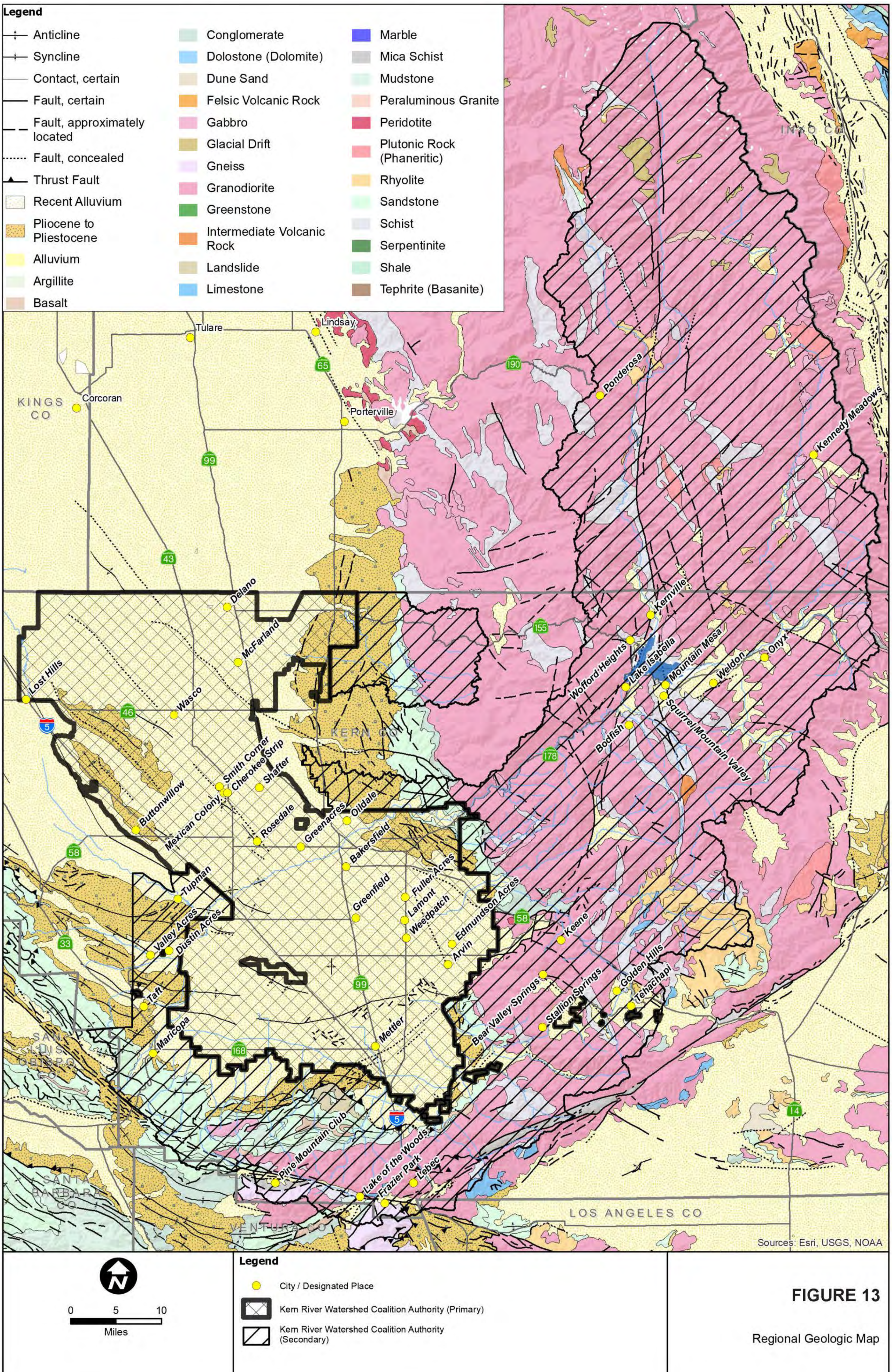


Figure 13. Regional Geologic Map

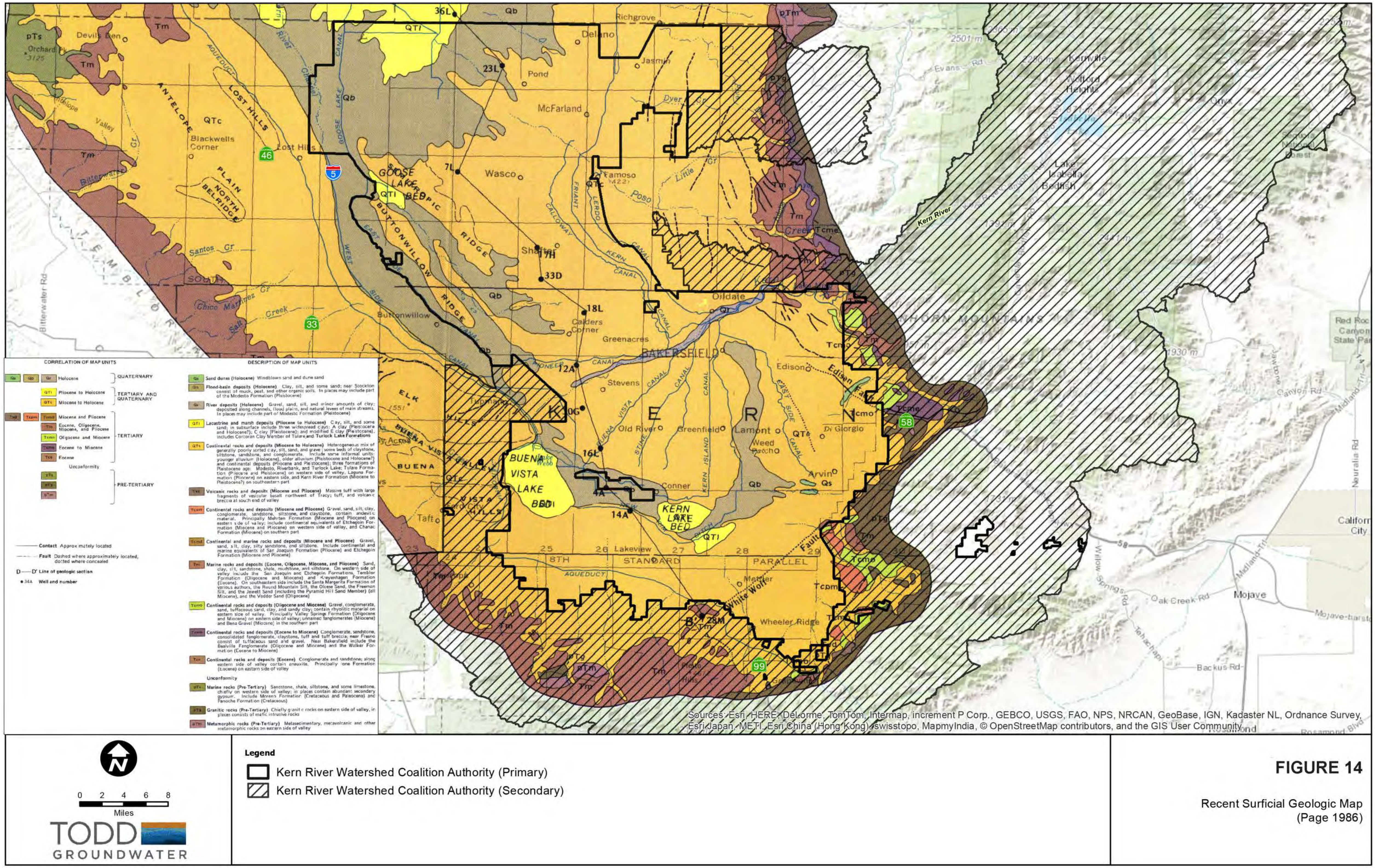


Figure 14. Recent Surficial Geologic Map (Page 1980)

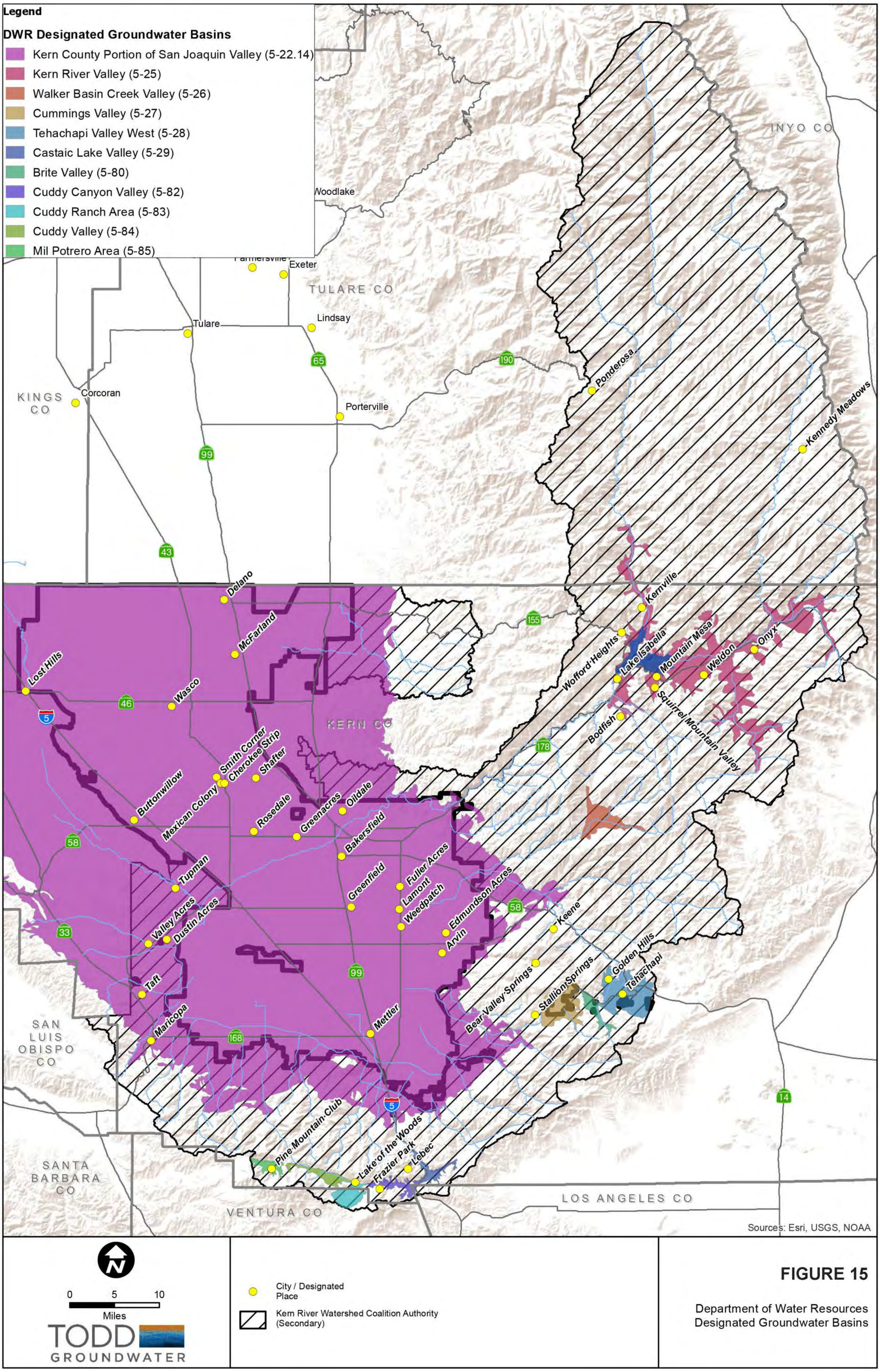


Figure 15. Department of Water Resources Designated Groundwater Basins

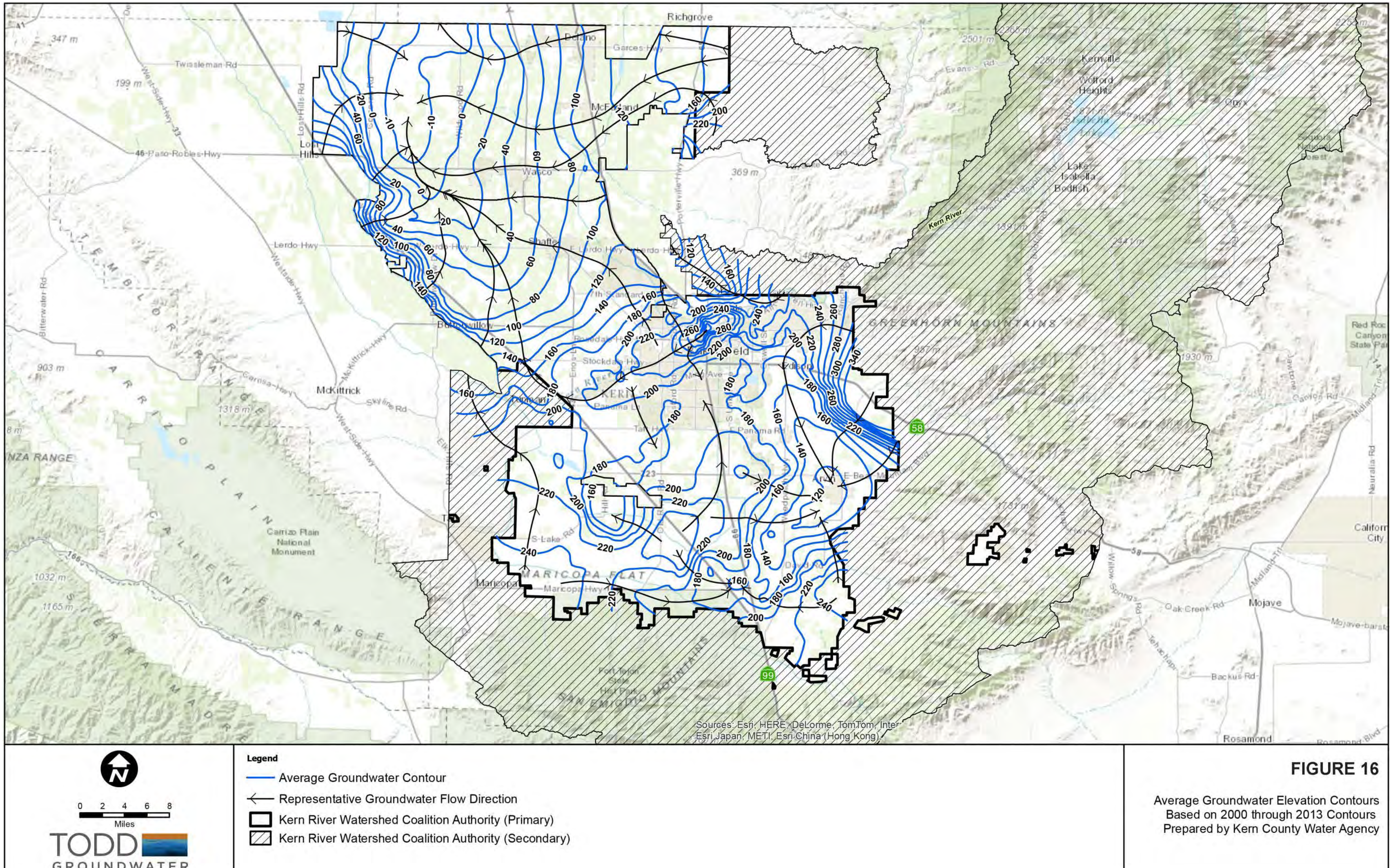
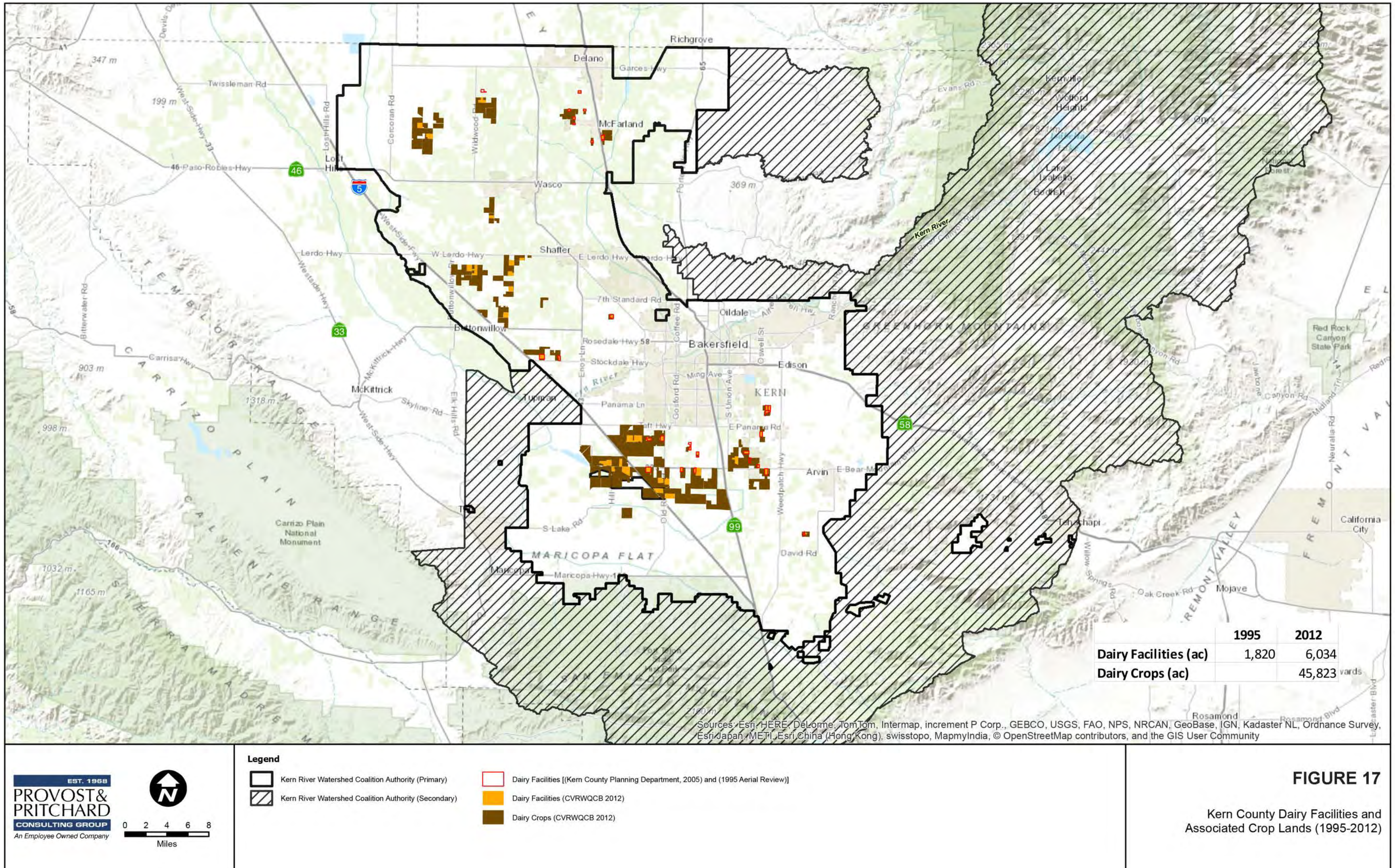
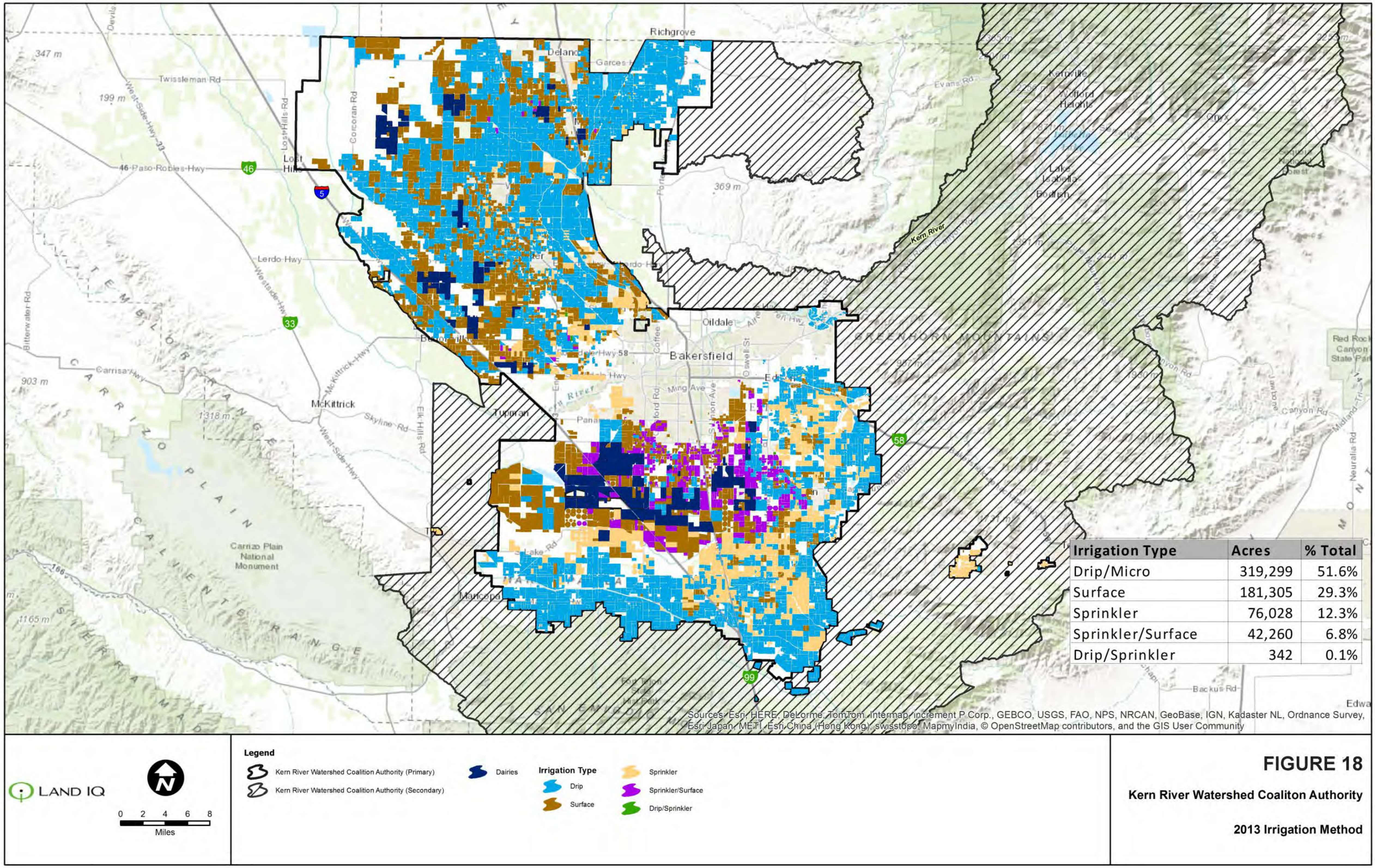


Figure 16. Average Groundwater Elevation Contours, Based on 2000 through 2013 Contours Prepared by Kern County Water Agency



	1995	2012
Dairy Facilities (ac)	1,820	6,034
Dairy Crops (ac)		45,823

Figure 17. Kern County Dairy Facilities and Associated Crop Lands (1995 – 2012)



Irrigation Type	Acres	% Total
Drip/Micro	319,299	51.6%
Surface	181,305	29.3%
Sprinkler	76,028	12.3%
Sprinkler/Surface	42,260	6.8%
Drip/Sprinkler	342	0.1%

Figure 18. KRWCA Irrigation Systems

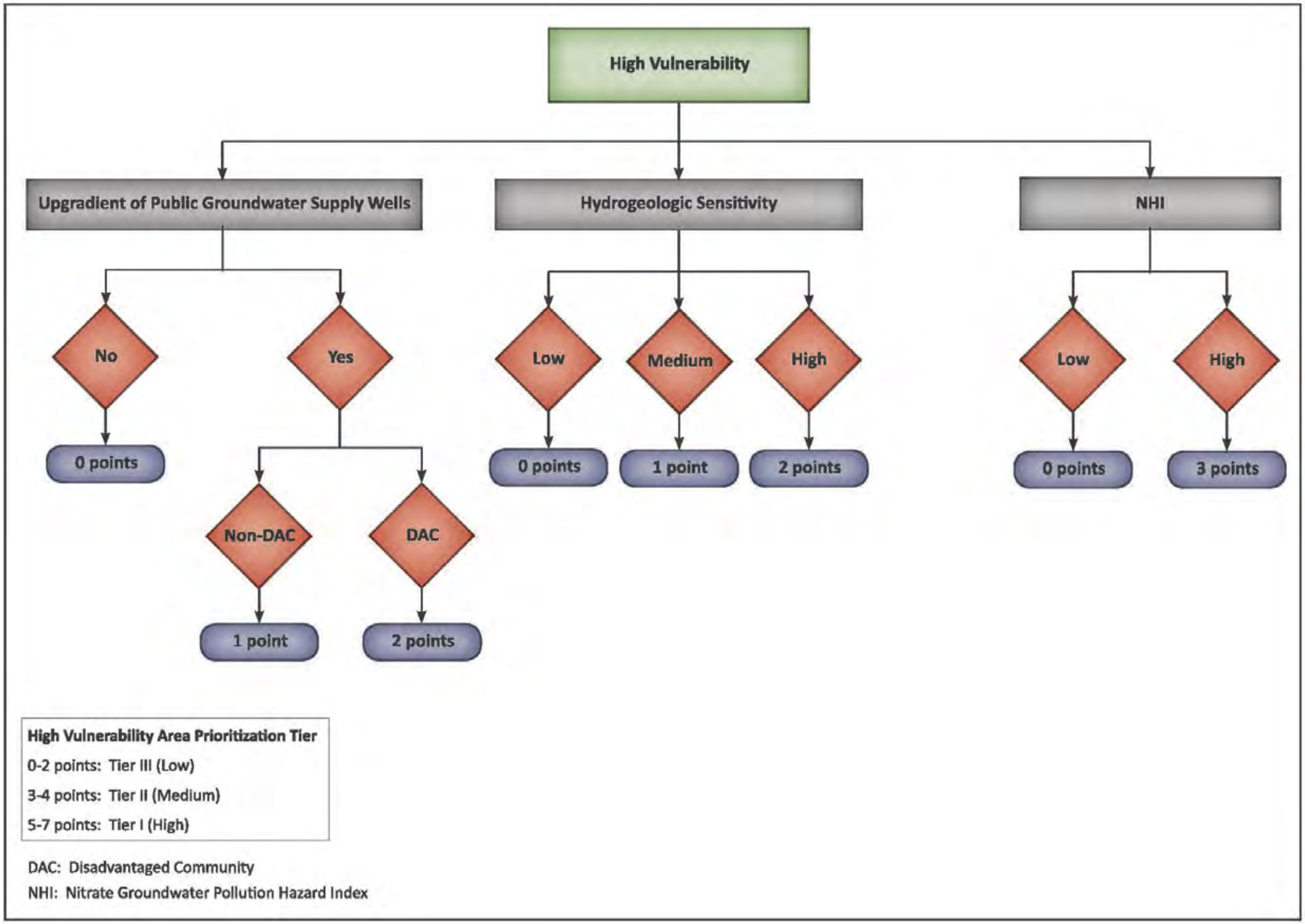
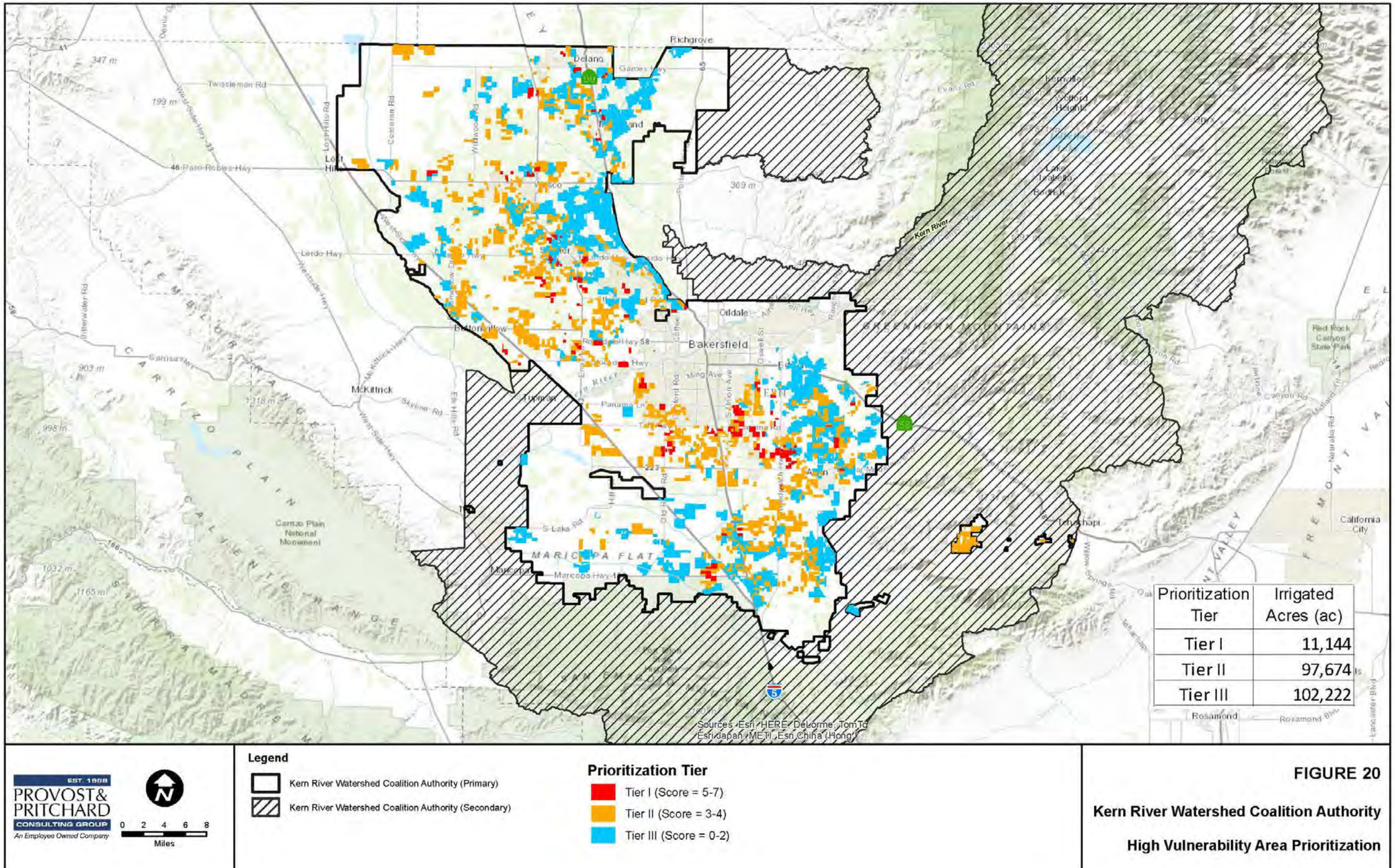


Figure 19. KRWCA Prioritization Framework Flowchart



Prioritization Tier	Irrigated Acres (ac)
Tier I	11,144
Tier II	97,674
Tier III	102,222

Figure 20. KRWCA High Vulnerability Area Prioritization

Table 2. High Vulnerability Area Prioritization Scenarios and Resulting Tiers

High Vulnerability Area Prioritization Scenarios and Resulting Tiers				
Upgradient of Public Groundwater Supply Wells	**Hydrogeologic Sensitivity**	**NHI**	**Points**	**Prioritization Tier**
DAC	High	High	7	Tier I
Yes	High	High	6	Tier I
DAC	Medium	High	6	Tier I
Yes	Medium	High	5	Tier I
DAC	Low	High	5	Tier I
No	High	High	5	Tier I
Yes	Low	High	4	Tier II
DAC	High	Low	4	Tier II
No	Medium	High	4	Tier II
Yes	High	Low	3	Tier II
DAC	Medium	Low	3	Tier II
No	Low	High	3	Tier II
Yes	Medium	Low	2	Tier III
DAC	Low	Low	2	Tier III
No	High	Low	2	Tier III
Yes	Low	Low	1	Tier III
No	Medium	Low	1	Tier III
No	Low	Low	0	Tier III

Table 3. KRWCA Prioritization Tier I Acreage by Crop and Irrigation System Type

KRWCA Prioritization Tier I Acreage by Crop and Irrigation System Type			
Prioritization Tier	**Crop**	**Irrigation System Type**	**Total Acres (ac)**
Tier I	Almonds	Surface	2,319
	Truck Crops	Sprinkler/Surface	1,108
		Surface	529
		Sprinkler	484
	Field Crops	Sprinkler/Surface	1,141
		Surface	776
	Potatoes	Sprinkler	1,299
		Sprinkler/Surface	240
		Surface	58
	Corn	Sprinkler/Surface	781
		Surface	447
	Cotton	Surface	865
		Sprinkler/Surface	65
	Tomatoes	Surface	217
		Sprinkler/Surface	77
		Sprinkler	4
	Alfalfa	Sprinkler/Surface	146
		Surface	146
	Fruit Tree	Surface	215
	Nut Tree	Surface	100
	Citrus	Surface	53
	Pasture	Surface	46
	Pistachios	Surface	27
		Total Acres (ac):	**11,144**

Table 4. KRWCA Prioritization Tier II Acreage by Crop and Irrigation System Type

KRWCA Prioritization Tier II Acreage by Crop and Irrigation System Type			
Prioritization Tier	**Crop**	**Irrigation System Type**	**Total Acres (ac)**
Tier II	Truck Crops	Sprinkler	11,060
		Surface	6,071
		Sprinkler/Surface	4,215
		Drip/Sprinkler	14
	Almonds	Surface	17,481
		Drip	1,103
		Sprinkler	36
		Sprinkler/Surface	264
	Potatoes	Sprinkler	12,679
		Surface	2,011
		Sprinkler/Surface	1,102
		Drip	50
	Field Crops	Surface	8,209
		Sprinkler/Surface	2,654
		Sprinkler	3
	Corn	Surface	5,216
		Sprinkler/Surface	4,413
		Sprinkler	2
	Cotton	Surface	7,499
		Sprinkler/Surface	268
	Pistachios	Surface	5,357
	Tomatoes	Surface	1,396
		Sprinkler	664
		Sprinkler/Surface	298
	Alfalfa	Surface	1,518
		Sprinkler/Surface	400
	Fruit Tree	Surface	1,736
		Sprinkler	79
		Drip/Sprinkler	38
		Drip	28
	Nut Tree	Surface	1,062
	Citrus	Surface	265
		Drip	83
	Grapes	Drip	159
		Sprinkler	144
		Surface	8
	Pasture	Surface	59
		Sprinkler/Surface	27
		Total Acres (ac):	**97,674**

Table 5. KRWCA Prioritization Tier III Acreage by Crop and Irrigation System Type

KRWCA Prioritization Tier III Acreage by Crop and Irrigation System Type			
Prioritization Tier	**Crop**	**Irrigation System Type**	**Total Acres (ac)**
Tier III	Almonds	Drip	32,663
		Sprinkler	1,250
	Grapes	Drip	20,394
		Surface	6,736
		Sprinkler	234
		Sprinkler/Surface	61
		Drip/Sprinkler	1
	Citrus	Drip	9,833
		Sprinkler	204
	Alfalfa	Surface	4,332
		Sprinkler	944
		Drip	178
	Field Crops	Sprinkler	3,679
		Sprinkler/Surface	756
		Surface	658
		Drip	238
	Truck Crops	Sprinkler	2,619
		Drip	2,451
		Surface	113
		Drip/Sprinkler	72
	Fruit Tree	Drip	3,294
		Sprinkler	590
	Pistachios	Drip	3,816
		Sprinkler	6
	Tomatoes	Drip	1,012
		Sprinkler	382
	Potatoes	Sprinkler	999
		Drip	227
	Corn	Surface	373
		Drip	4
	Nut Tree	Sprinkler	75
		Drip	8
	Pasture	Sprinkler	17
		Drip	1
		Total Acres (ac):	**102,222**

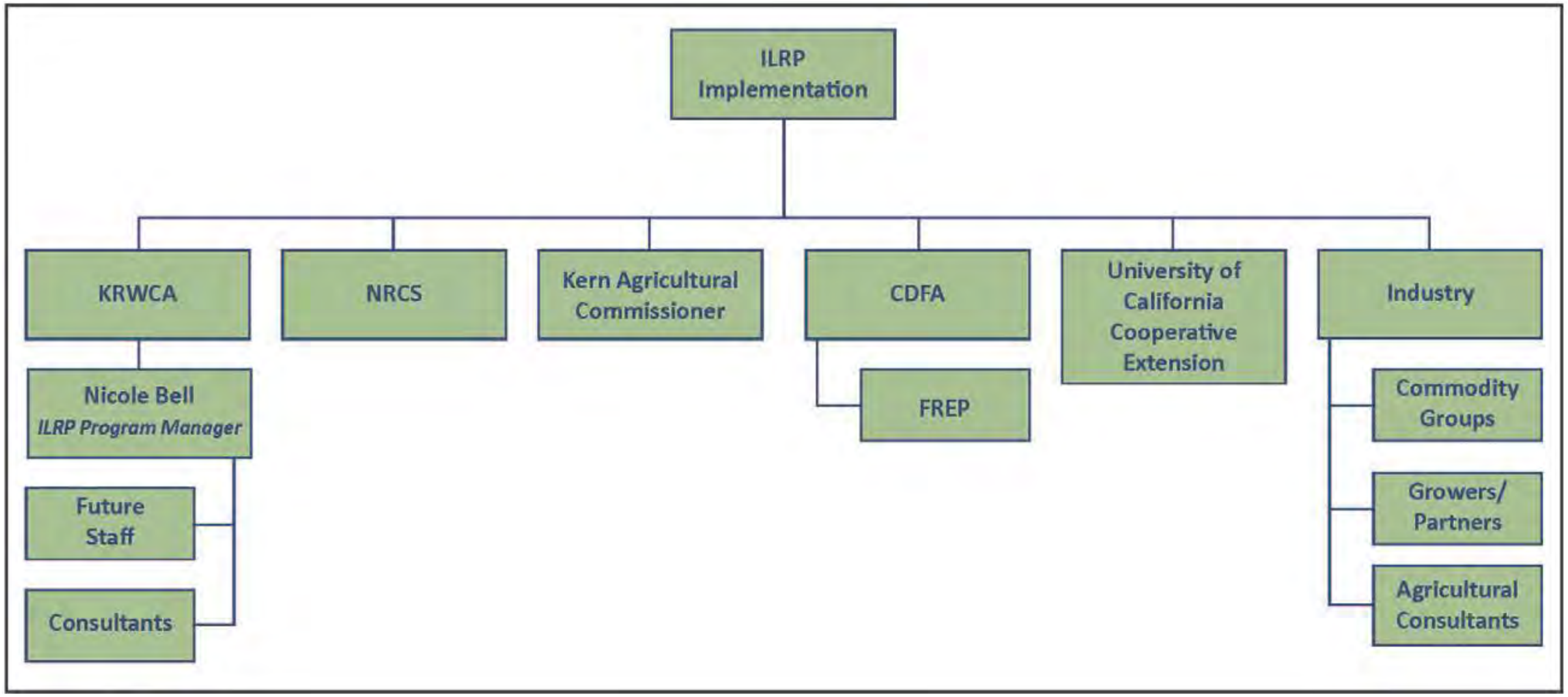


Figure 21. Management Plan Organization Chart

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